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ENERGY/ECONOMIC ANALYSIS OF ACTIVE RESIDENTIAL SOLAR MODELS

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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ENERGY/ECONOMIC ANALYSIS OF ACTIVE RESIDENTIAL SOLAR MODELS

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July, 1981

Prepared for

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Renewable Energy and Conservation Program
Grant Agreement Number 943-801

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INTRODUCTION

The success of any solar installation is dependent upon the thermodynamic efficiency of the system. Until recently the solar industry has concentrated on percent solar fraction as an incentive to go solar. This has created a multitude of idealogical designs which have yet to catch on in the mass market. Obviously the efficiency of any system is critical, but the ultimate decision to go solar rests with the ability of the system to return its investment in energy savings.

The purpose of this project is to focus on the economic evaluation of active solar systems. The project can be broken into four tasks:

1) A determination of the projected cost of energy by type.
2) The selection of an appropriate discount rate for cost comparison.
3) A review of available energy/economic computer models for active solar heated residential systems.
4) The incorporation of the Montana Solar Data Manual into selected computer models.

Tasks 1 and 2 involve a review of available literature and forecasts made by independent research firms as well as those made by this region's utility companies. Tasks 3 and 4 are technical to the extent that they involve acquisition of computer models and installation of those models into a computer system with access available to the Montana Department of Natural Resources and Conservation (DNRC). The intent is not to attempt verification of the computer models, but to refer to the DNRC, specifically the Renewable Energy Bureau, Western Analysis' opinion of which model(s) would best suit its needs for assisting the movement of Montanans toward solar energy. Our focus must remain on the final user--the average citizen. Our ultimate goal is to bring to Montanans a method for evaluating their home's potential for solar energy.

COMPUTER MODEL EVALUATION

The first activity in model evaluation was to research the availability of computer models which simulate active solar systems for residences. The search focused on the belief that the models selected to evaluate should require a minimum amount of pre-calculations, be able to accept the data from the Montana Solar Data Manual, and perform technical calculations without requiring the user to be an expert in solar engineering. Although the search was hoping for a model in which a maximum number of users were available, it was conceded that the running of any computer model requires a familiarity with the computer system itself.

The next step was to research the requirements of solar models in an attempt to outline minimum inputs which the model should address itself to. Our preliminary analysis of models produced the following questions necessary for the review of the computer models.

A. System Components

1) What is the method of heat load (or loss) calculation?

2) How is collector efficiency determined?

3) Does the model compute an optimal collector size and fixed collector area?

4) Does the model allow for integral systems, i.e., combining domestic hot water heating, space heating, and a storage system?

5) Will the model accept several transfer mediums, i.e., air, water, antifreeze solution, etc.?

6) Are component efficiency ratings incorporated, i.e., of heat pumps, heat exchangers, etc.?

7) Will the model calculate an optimal storage facility based on the solar collector size?

8) What data base is required?

   a) Site-specific insolation data.
   b) Horizontal or angular insolation.
   c) Time increments.
   d) Ambient temperatures.

B. System Costs

1) Are the following component costs specified?

   a) Collector costs.
   b) Storage tank costs.
   c) Control costs by item, i.e., thermostats, pumps, valves, etc.
   d) Installation costs.
   e) Engineering/design costs (fixed).
   f) Heat exchanger costs.
   g) Annual maintenance.

2) Does the model accept per unit costs only or total system costs (buying a total pre-constructed system)?

C. Personal Financial and Tax Data

1) Does the model account for the following?

   a) Loan term.
   b) Down payment.
   c) Additional insurance costs.
   d) Inflation.
   e) Personal income tax bracket.
   f) Discount rates.
   g) Property tax re-evaluation due to home improvements.

D. Reference System Costs

1) Are auxillary and replacement heat costs specified?

2) Are annual maintenance costs of the displaced system included in payback?

3) How are the energy cost escalations treated?

E. Output Requirements

1) Does the model output the following?

   a) Optimal component sizing.
   b) Solar fraction.
   c) Useful solar BTUs per day per square feet of collector.
   d) Estimated auxillary energy required.

2) Are the following included in the cash flow summary?

   a) Fuel savings.
   b) Tax savings.
   c) Loan payment.
   d) Interest.
   e) Payback time for fuel savings to equal investment.
   f) Payback time for the net cash flow to equal investment.
   g) Internal rate of return.
   h) Annual percent load derived from solar.
   i) Net present worth.

F. Special Considerations

1) What language is the model available in?

2) What are the minimum memory requirements?

3) On what medium is the model stored, i.e., tape, cassette, cards, etc.?

4) Is the model restricted to system type, i.e., TRS-80, IBM, HP-85, etc.?

5) Is the program in conversation mode or by batch input only?

The following vendors were contacted in an effort to obtain any information available on the various models. Since our scope of work does not include actual model acquisitions, the first step was to seek promotional literature and user's manuals and to conduct personal conversations with many of the designers of the models. Exhibit 1 shows a list of vendors or sources contacted. All responded, except Omni Systems and S & W Associates.

Most of the models currently available are offshoots of the two original models, FCHART and SOLCOST. Both models were developed under federal grants; consequently, documentation is easily obtained and extensive verification has been made. SOLCOST and FCHART require main frame computer systems. The principal advantage of the other models is that they have been designed for micro systems. However, very little testing has been made and pre-purchase information is only sketchy.

Exhibit 1. Vendor/Source Contacted.

Model	Vendor/Source	Cost to Purchase
FCHART - 4.0	Mechanical Eng. (MSU)	\$200
SOLCOST - 3.2	Solar Environmental Eng. Co.	\$200
G-CHART*	Solar Energy Design Corp.	\$25/worksheet
SEIM	MC^2 Programs	\$195
SEEC-FCHART	Solar Environmental	\$200
TRSOL1 & NUPASS	Omni Systems	\$50
HC-CHECK	S & W Associates	\$200/year

*G-CHART is a worksheet obtained from J. Lee Cook of the State Solar Office.

Rather than gamble on untested programs, the decision was jointly made between the Renewable Energy Bureau and Western Analysis to concentrate further evaluations on SOLCOST and FCHART. Western Analysis purchased SOLCOST from the Solar Environmental Engineering Company and FCHART was borrowed from the Mechanical Engineering Department of Montana State University. Both programs were installed on the Honeywell CP6 at Montana State University. Sample problems were then run on both systems to verify installation.

A substantial amount of project time was spent on installing the programs. SOLCOST (Version 3.2 September 1980) came with very little documentation from a programming viewpoint and required flowcharting the main program. SOLCOST also required a large amount of memory to be compiled, in fact, a shortened version of the interactive program was finally installed. The SOLCOST authors have made every attempt to keep their program as standard as possible despite some sacrifice in efficiency and memory requirements. There were, however, several areas which required actual program modifications. One particular error involved an argument error between interacting routines and another involved poorly used equivalence statements. Both errors, however, were corrected and confirmed by Solar Environmental Engineering Company representatives.

FCHART (Version 4.0 September 1980) was a different situation. The program compiled successfully the first time and then proceeded to continually create run time errors which were difficult and costly to trace. The biggest problem with FCHART was the lack of standardization in the program. FCHART does not initialize many of its variables to zero prior to running although the program assumes they are set. For instance, if the variable NVOPT was set to zero, the program was not to calculate the optimal collector area.

Since this variable was not preset to zero, initial runs sent the program in a direction where values for other parameters were unknown, producing run time errors. A second problem which required assistance from systems personnel at Montana State University involved the loss of memory addresses. Briefly explained, the actual values of variables were modified by so many dummy arguments between surbroutines that the original memory addresses were lost, confusing the computer to the point that it would lose track of variable values. Consequently, some of the variable names and common blocks had to be modified. Further complications occurred in the simple fact that some of the economic payback periods were calculated incorrectly and had to be recoded.

MODEL DESCRIPTIONS

FCHART

FCHART is an interactive program written in FORTRAN developed at the Solar Energy Laboratory, University of Wisconsin, Madison, Wisconsin. The program was developed from the original work performed by W.A. Beckman, S.A. Klein, and J.A. Duffie. The program incorporates design methods for active solar heating and heat pump heating systems. System performance is determined from equipment characteristics and monthly average meteorological data. The program can be used for residential and commercial buildings.

The program is built around a default system set up in Madison, Wisconsin (see Appendix A for the system components of the default system). The user simply modifies this basic system to meet his design by changing the appropriate parameters. The program will perform thermal analysis (in English or metric (SI) units) and economic profiles. The emphasis has, however, been toward the evaluation of the solar fraction. The economic portion of the program is somewhat disappointing and is discussed further in a different section.

Some very powerful features are available in FCHART. A routine can be implemented to compute optimal values for a multitude of variables. For example, optimization might be warranted for collector size, storage size, or discount rate. Another feature allows for stepping parameters, thus, giving the user the opportunity to test various component sizes. One may want, for instance, to test the effect of different collector angles by "stepping" the program through 10 degree increments (40, 50, and 60 degree inclines).

The documentation within the program is straightforward and easily followed, provided one is fully aware of the components of the system. Once the type of system is specified (active, collector, transfer, storage, etc.), the default parameters can be listed and then modified to reflect values for the system being modeled. The results of thermal analysis produces solar radiation incident on the collector, average ambient temperature, space heating load, water heating load, total load, useful energy gain of the collector, energy lost in storage, change in internal energy of storage, and fraction of total load delivered from non-purchased energy.

The economic analysis will produce a summary of energy used and associated costs which would have been purchased with the conventional system currently in place and a life cycle cost of the proposed system, including loan profiles and energy costs summaries.

FCHART stores the results of each analysis as if it were a reference system against which other alternatives can be compared. By utilizing this feature, the user can input his conventional system by specifying a collector with no area and wait for the program to compute the monthly cost of energy used. Once this system has been stored, the parameters can be modified to reflect a proposed solar system. FCHART will then conduct a cash flow based on energy savings and investment costs between the reference and the current proposed systems. When finished, a payback analysis is performed.

FCHART also conatins a feature which allows the user to store his system description for later runs. This is done by typing KEEP and then a logical unit number which will write the sample problem and associated data to the file linked with the logical unit. This in itself is an extremely cost effective feature.

Weather data can also be input to the program and a new data base created and saved if the user wishes to use his own data. Fuel price escalations are either input as a base price with an annual inflation factor or as a sequence of costs through each year of analysis. The prices are in terms of $/MMBTU which requires some conversions from the common $KW/hr. Fuel comparisons are allowed for electricity, natural gas, and fuel oil. No monthly service charge can be input. The base rate of $2.67 per month for electrical service is ignored, which over 20 years produces an error of over $640.00.

The program currently requires 58K to run on the Montana State University system. The memory requirements can be reduced by setting up an overlay structure which links only interacting routines together. The final requirements are not known since the procedure would require separate compiling for 58 subroutines and the main program. Since the CP6 system handles the program easily, the overlay structure was not utilized.

SOLCOST

SOLCOST was developed by Martin Marietta for the U.S. Department of Energy's (DOE) Division of Solar Energy, Research and Development Branch. It is currently being maintained and updated by the Solar Environmental Engineering Company. SOLCOST has not undergone as extensive verification as has FCHART, but preliminary tests currently being funded by DOE have shown that the space heating and water heating analyses are representative of actual systems.

The Version 3.2 installed for this project utilizes an interactive feeder program which builds an input file for the main program to use. This feature combines two types of programs--interactive and batch. The batch mode is especially appealing to users who wish to perform multiple analysis since the original inputs are stored in a file. The batch mode is also less expensive to use.

SOLCOST contains a set of default values for each equipment type rather than a sample problem as FCHART utilizes (see Appendix B for default values). As can be seen, one of the obvious disadvantages is the multitude of inputs required by SOLCOST. Fortunately, a large number of the questions can be avoided as will be shown later in the sample problems.

One especially welcome feature of SOLCOST is its ability to accept defaults for heating and cooling loads. The user can enter monthly fuel records, specify that the house meets certain standards, or supply his own heat load based on a conventional load calculation. FCHART requires that this be performed in advance.

Another outstanding feature incorporated allows for the input of an escalation table for energy prices. SOLCOST also includes coal and liquified petroleum (LP) gas in addition to electricity, natural gas, and fuel oil.

Multiple collectors connected into a series, with each having a different efficiency rating, are also allowed. FCHART, on the other hand, requires a single efficiency rating. The value of this routine and the methodology will not be considered here.

Collector optimization is calculated in SOLCOST in a similar method to that of FCHART. However, the program does not allow the optimization of individual parameters. This would require an iterative procedure with the parameters being changed "by hand." The best tilt angle is calculated based on steps; default steps are latitude, latitude + 7.5 degrees, and latitude + 15.0 degrees. Users may supply up to three of their own tilt angles but the multiple "stepping" feature of FCHART is not present.

All thermal analyses are in English units only. The program computes the solar gain by running a one day simulation on the 15th day of the month. (See Appendix A and B of the User's Manual for the methodology.) This requires two radiation profiles--one for a clear day and one for a cloudy day. The insolation values are sent to the solar performance routine where they are used with the time variant ambient temperature and inlet temperatures at dawn. The procedure checks the storage temperature at dawn against the previous dawn value. If the difference is outside a reasonable limit (i.e., the load for space heating is greater than the stored energy), the analysis is repeated with the proper allocations made until the dawn temperature of storage is within the reasonable limit. The end result is the storage losses and auxillary energy levels. Output in tabular form is the storage temperature at dawn, temperature maximum, average temperature, storage losses, auxillary energy, and the number of iterations run for the calculations to converge to an allowable storage temperature at dawn.

Other thermal reports include a monthly solar fraction, average useful solar per day by month, total useful solar energy by month, average auxillary energy used, and conventional system energy required without solar energy. Also output are optimal collection size and collector tilt based on the economic analysis.

The economic analysis includes fuel savings, maintenance, insurance, and property tax, depreciation, loan interest, income tax savings, loan payments, and net cash flow. Calculations are made for payback of fuel savings to equal total investment, payback for net cash flow to offset down payment, net present worth, rate of return, annual solar load provided by solar, and annual energy savings with the solar system. SOLCOST will also plot percent solar energy versus collector area, discounted savings versus collector area, and cash flow status versus life of system.

SOLCOST requires 53K of memory to run. This could also be lowered, based on the overlay principal outlined previously.

SOLCOST will also allow uses beyond that addressed in this report. Those uses include commercial buildings and institutional analysis, and heat pump and absorptive cycle air conditioning analysis. An attractive feature allows calculations for weatherization improvements to an existing residence.

PRE-PROGRAM CALCULATIONS

Two of the systems components, heat load and collector efficiency, as well as the parameters associated with them, require special attention prior to performing a solar analysis.

Considerable time was spent researching methods of heat loss (or load) calculations for the residence being modeled. In order for any model to project a solar fraction or payback period, the system must first be sized to meet the heat demand. The homeowner who has not substantially altered his weatherization during the past several years has his past consumption records to assist him. These records coupled with the degree day data base make the models work fairly straightforward. In new homes or homes recently weatherized, however, these consumption records are non-existent. Therefore, it is necessary that the homeowner perform a detailed energy audit including an analysis of conduction and convection coefficients for construction materials, infiltration losses through "cracks" in doors and windows, insulation values, window area, etc. Some models accept ASHRAE STD 90-75 method in place of the home energy audit. ASHRAE sets certain standards for dwelling types and if the residence meets these standards, they can be used instead of performing the calculations.

The degree day method of calculating the amount of heat required to maintain a comfortable indoor temperature is dependent upon the difference between the indoor and outdoor temperature. One degree day occurs for every degree the average outside temperature is below 65^{o}F (18.3^{o}C) for a 24 hour period. If, for example, the outside temperature is a constant 40^{o}F for a 24 hour period, 25 degree days are accumulated $\left[(65 - 40)^{o}\text{F} \times 1 \text{ day} = 25 \text{ degree days}\right]$.

The heat load is considered to be proportional to the number of degree days. When past consumption records are available, the heat load, called the building overall energy loss coefficient-area product (UA), is calculated as the amount of energy required to heat the building for a given period divided by the number of degree days occurring during that period. A consideration is paid to the relative heating value of fuels and furnace efficiency. Mathematically, the equation becomes:

$$UA = (N_F + H_F + EFF_F)/DD .$$

where N_F is the number of units of fuel consumed, H_F is the heating value of the fuel, and EFF_F is the efficiency of the typical furnace. Exhibit 2 shows different heat values of fuels and the typical furnace efficiencies.

The heating load for new constructions can be produced in two fashions--by actual calculations of heat loss or by utilizing the ASHRAE standards for thermal conduction. The actual loads calculations can be made by following a procedure such as that outlined in "The Montana Renewable Energy Handbook" and a similar more detailed method appears in "Other Homes and Garbage." This home energy audit can become very detailed and could require assistance from an engineer. A brief description of the methodology follows.

1) Calculate the rate of heat transfer per square foot for the various materials which comprise the exterior surfaces. These rates include heat flow through the material (conduction) and across the material (convection).

2) Determine the total losses for the walls, roofs, doors, and windows from these transfer rates and the area of each surface. For example, the heat losses through a wall include the rates for plywood, siding, insulation, and window glass.

Exhibit 2. Heating Value of Fuels.

Fuel	BTUs/Unit	Furnace Efficiency
Natural Gas	10^6 BTU/mcf	.70
Fuel Oil (#2)	139,600 BTU/gal	.65
Electricity	3,413 BTU/KW-hr	1.00
LP Gas	91,500 BTU/gal	.70
Coal	30×10^6 BTU/ton	.65
Wood (Douglas fir)	20,000 BTU/cord	.60

3) Calculate infiltration losses by either determining the number of air exchanges per hour or by using the crack estimation method which calculates the losses as a portion of the linear perimeter of all window and door "cracks."

4) The total heat load is then computed by adding the heat transfer losses and the infiltration losses, then multiplying by the number of degree days for the period of calculations, then multiplying by 24 since the transfer rates were in hourly rates, and finally dividing by the difference of the inside temperature (65°F) and a design temperature for which the structure was built. The design temperature is nothing more than the coldest day which can reasonably be planned for.

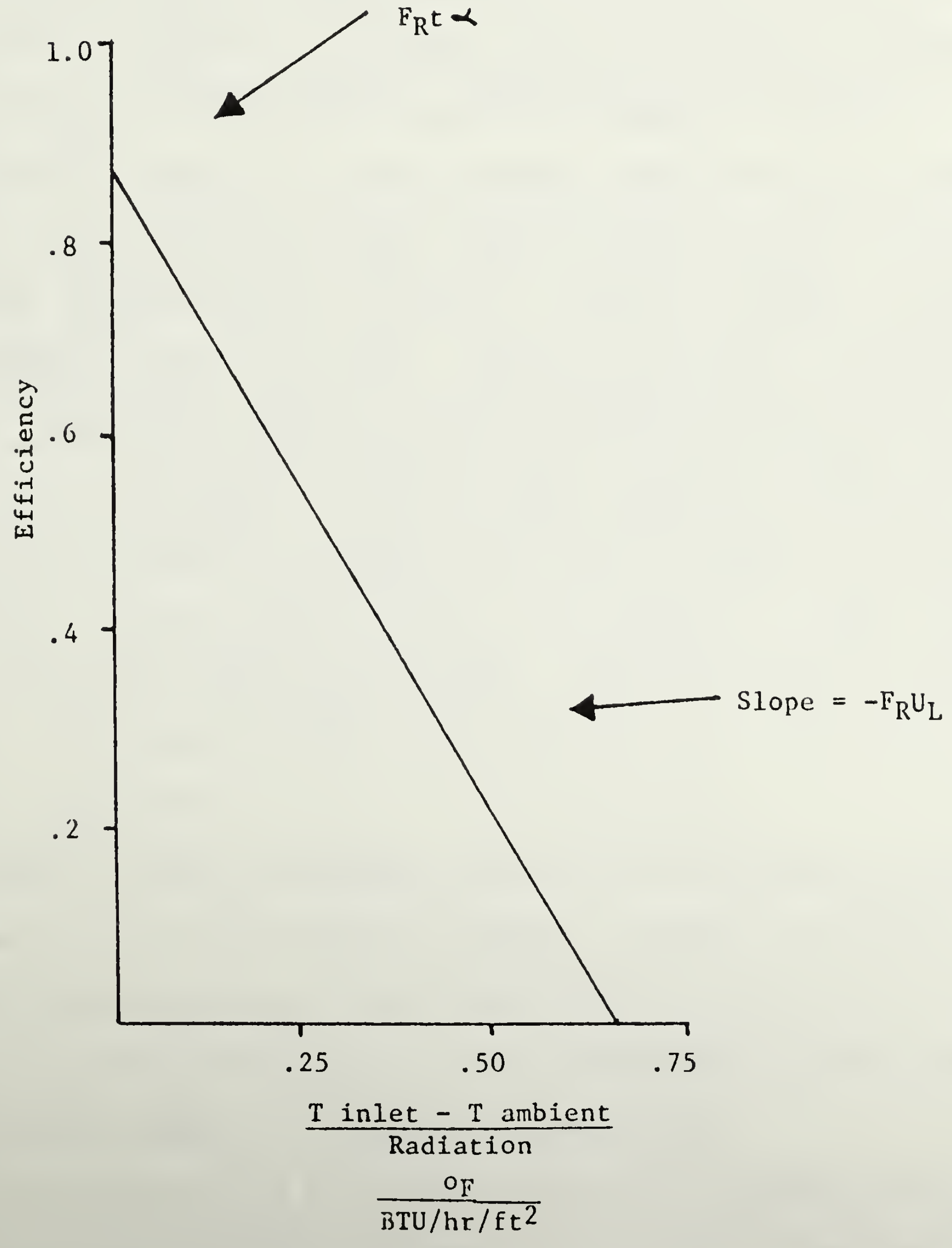
Constructing the building to meet the ASHRAE standards of thermal conductance can simplify the loads calculations for some models. For example, SOLCOST will compute the heat load for such a construction from measurements of wall area, ceiling area, window perimeter, sliding glass door area, swinging door area, floor area, and slab perimeter. More information concerning the standards can be obtained from ASHRAE Std 90-75 Energy Conservation in New Building Design.

Many collectors currently on the market have been tested by a reputable testing facility. Efficiency ratings are based on the collectors' ability to deliver available radiation on the collector surface to a transfer medium. The collector efficiency is defined as the ratio of the heat removed by the coolant divided by the incident solar energy. Standard practice is to plot collector efficiency as a function of the parameter T/Q, where

$$\frac{T}{Q} = \frac{\text{Average Collector Coolant Temperature - Temperature}}{\text{Incident Solar Radiation}}, \frac{^{\circ}\text{F}}{\text{BTU/ft}^2\text{/hr}}$$

The efficiency of a collector decreases with increasing operating temperature and decreasing radiation density. A typical collector efficiency curve approximates a straight line (see Figure 1). The point where the line

Figure 1. Typical Collector Efficiency Curve.



intercepts the y axis (efficiency at 0^{o} temperature difference divided by the radiation in the collector) is represented by the symbol $F_R t\alpha$ (FR - TAU - ALPHA). This variable represents the product of the collector efficiency factor, the glazing transmissitivity, and the collector's absorbativity. The variable $F_R U_L$ (the product of the overall heat loss coefficient and the collector efficiency factor) represents the slope of the efficiency curve. The curve also indicates that as the collector temperature rises, thermal losses approach the amount of absorbed radiation and collector output diminishes.

Future discussion of collector efficiencies is unwarranted at this point, but anyone using a computer model must be aware of the presence of the two variables, $F_R t\alpha$ and $F_R U_L$. Both variables are usually required as inputs. Whenever purchasing a collector, the buyer should ask for all literature on any collector tests. The testing specifications will provide the efficiency ratings which the models require. If collector efficiencies are unavailable, typical default values for types of glazings, number of covers, and transfer fluids are available and can approximate the actual efficiency of a manufactured collector. However, if the specifications are not available, it would be advisable to go elsewhere to purchase a collector.

WEATHER DATA

SOLCOST and FCHART utilize solar data collected by the U.S. National Oceanic and Atmospheric Administration. This data was recently rehabilitated producing the SOLMET data base. The U.S. Department of Energy recently recommended that the SOLMET data be used in all simulation and design work. The base contains horizontal radiation for 248 locations and has been averaged over a 24 to 25 year period. Approximately 20 locations have partial data only.

Horizontal radiation data has potential sources of error as outlined by Fowlkes in the Montana Solar Data Manual. The data collected by Fowlkes has "believability" since it is actual measured data, whereas the SOLMET data is based on "theoretical" values. When using Fowlkes' data it is interesting to note that it is consistently more conservative than that of the SOLMET data, but when it does show increased values they occur where they should be: under low altitude of the sun and/or snow conditions of winter. See Exhibit 3 for sample comparisons of Fowlkes' and the SOLMET data for three locations. In this case, Fowlkes' data has been converted to a horizontal surface for comparisons.

FCHART has added 12 Canadian locations to the data base and does not include the cities where data is incomplete. SOLCOST contains all 248 locations, 25 Canadian cities, plus an additional 63 locations can be simulated through an internally constructed data base calculated by a routine based on percent possible sunshine for estimating radiation data.

Solar radiation data from Fowlkes' engineering required modification prior to acceptance by SOLCOST and FCHART. Since FCHART accepts angular data,

Exhibit 3. Horizontal Radiation.

		KJ/M^2/Day		BTU/FT^2/Day	
Location	Month	Fowlkes	FCHART	Fowlkes	SOLCOST
Billings	January	5524	5516	486	486
	February	8506	8661	748	763
	March	13119	13499	1155	1190
	April	17767	17322	1564	1526
	May	19446	21708	1712	1913
	June	22527	24669	1983	2174
	July	22300	27053	1963	2384
	August	19994	22952	1759	2022
	September	16960	16683	1492	1470
	October	11025	11199	970	987
	November	6321	6371	556	561
	December	4258	4780	374	421
Helena	January	4836	4760	426	419
	February	7800	8044	686	709
	March	12686	13000	1116	1146
	April	18266	16874	1608	1487
	May	18392	21111	1619	1860
	June	20917	23149	1841	2040
	July	20314	26486	1788	2334
	August	19048	21906	1677	1930
	September	16189	16030	1425	1413
	October	10617	10512	934	926
	November	5723	5915	504	521
	December	3744	4135	329	364
Missoula	January	4134	3539	364	312
	February	5780	6516	509	574
	March	10926	11139	962	982
	April	16175	15686	1424	1382
	May	16992	20230	1496	1783
	June	21332	21937	1878	1933
	July	21600	26415	1901	2328
	August	19744	21346	1738	1881
	September	14188	15410	1249	1358
	October	10167	9221	895	813
	November	4398	4655	387	410
	December	2565	3033	226	267

all that is necessary is a conversion from KWH/M^2/Day (Fowlkes) to KJ/M^2/Day (FCHART). This required multiplying Fowlkes' data by a factor of 3600 (1 KWH/M^2 = 3600 KJ/M^2). The slope and azimuth were input as 60.00 (degrees) and 00.00 (due south), respectively. Fowlkes' data was then added to the FCHART data base effectively increasing the number of cities from 244 to 274. The horizontal data for the nine Montana cities originally in the FCHART weather file remain intact even though the newer data has been added.

SOLCOST produced special problems since the program only accepts horizontal insolation data. Loren Lantz of Solar Environment Engineering Company, Inc., referred me to work performed by Klein and Theilacher of the Solar Energy Laboratory at the University of Wisconsin, Madison, Wisconsin, the authors of FCHART. Their work, contained in the abstract "An Algorithm for Calculating Monthly Average Radiation on Inclined Surfaces," was recommended as a method for converting angular radiation to horizontal radiation. The same algorithm is currently contained in the computer coding of FCHART. The methodology then could be accomplished by running the Montana data through FCHART and dumping the data out by setting up a collector at 0 degrees.

Further investigation into the algorithm in FCHART revealed that regardless of the angle which data is collected and the slope of the collector, FCHART will first convert tilted data to horizontal data and then another conversion made to the slope of the collector. For example, if the data was measured on an instrument set at 60 degrees and the solar collector was also set at 60 degrees, FCHART would first convert the data to 0 degrees and then back up to 60 degrees when running a simulation. Regardless then of the program (SOLCOST vs FCHART), the Montana data has to be transformed, creating the error risk outlined in Fowlkes' Montana Solar Manual. This risk cannot be avoided unless a program is changed so that all solar installations are arranged at 60 degrees and due south.

The additions made to the FCHART weather file are compiled in Appendix C. The first line contains the city code, name, latitude, slope of insolation data, and the azimuth of insolation data. The next three lines contain monthly averages for solar radiation in KJ/M^2/day, heating degree days (Celsius), and ambient temperature (Celsius), respectively.

Fowlkes' data was converted from 60 degrees to 0 degrees insolation by intercepting a sample run of FCHART at the point where it had converted the data to 0 degrees (untilted the data). This data was converted to English units prior to "untilting." This resulted in data which SOLCOST would now accept.

SOLCOST's weather file contains a clearness factor which accounts for local atmospheric water content and variable aerosols. This factor modifies the data base and adjusts the site from the theoretical "clear day" radiation. The sites in Montana all contain a clearness factor of 1.04, which corresponds roughly to 1 percent per 1,000 feet in elevation. Fowlkes' verification of his own data included a clearness factor of 1.045, which brought the SOLMET data in line with his. When the model uses Fowlkes' data, the clearness factors would have to be set at 1.00 since the actual data does not require the clearness adjustment.

Another "plus" in using Fowlkes' data is that the modeler should not have to make assumptions concerning ground reflection. Consequently, when running SOLCOST or FCHART the ground reflection level should be set at 0.00. SOLCOST also requires a fraction of possible sunshine. This fraction is not required if radiation data is input. Consequently, the SOLCOST data base contains twelve 0.00's for the monthly fractions of possible sunshine when using Fowlkes' data.

Appendix C contains the additions made to the SOLCOST weather file. The first line contains the city code, latitude, clearness factor, and name. The next four lines contain monthly averages for minimum daily temperature (Farenheit), maximum daily temperature (Farenheit), percent possible sunshine, degree days (Farenheit), and horizontal radiation (BTU/FT^2/day).

MONTANA ENERGY FORECASTS

A fundamental portion of any economic analysis is the inclusion of the "do nothing" alternative. Any investment must be evaluated against the system which it professes to replace. In the solar energy field, this "do nothing" alternative is the conventional heating system. The conventional heating system may be new, in need of repair, or simply outlived its usefulness. Whichever the case, it has a series of cash flows just as the newer alternative of solar energy.

The most critical cash flow item of the conventional system is the assumptions one makes concerning the price of fuel which the system uses. Relatively stable are the annual maintenance costs, the furnace efficiency, and the space heating requirements of the home. Understating the future price of fuel could result in staying with a conventional source which is feasible now, but five years from now could become an albatross. Overstating the cost of fuel could cause one to commit a large amount of funds to a project which actually never will return its investment during its useful life.

Our intent here is to consolidate expert views concerning where the future of prices will be 10 or 20 years from now. Obviously, no one can make any guarantees that their forecasts will be correct. The energy picture can change drastically at any point in time as long as we are dependent upon supplies from areas which we have little control over. Additionally, any projected fuel prices cannot reflect your own opinion concerning non-renewable resources. A marginal investment may be extremely attractive to someone seeking energy independence and/or concerned with the depletion of non-renewable resources.

The following exhibits outline the viewpoints of several sources. The projections made by the utility companies were a result of a request by the Montana Public Service Commission that the utilities provide an unofficial forecast of energy prices through the next ten years. These forecasts must be considered as an estimate at best and may reflect "wishes" by the utilities. At any rate, they are included here for your information.

Electricity prices in Montana during the past decade have run substantially behind the national average. This cannot be expected to continue since any expansion of energy generation in this area will come from sources other than the formerly inexpensive hydroelectric power. Montana Power Company's forecast shows a substantial increase in rates during 1984 and 1985, when Colstrip 3 and 4 are expected to begin operation. Another huge increase is expected in 1990, when Resource 89's costs are passed through to the consumer.

Natural gas prices are closer to the national average, but are bound to be affected by the deregulation of domestic natural gas, Canadian price increases, and Anaconda Company closures within the state. These events will particularly affect Montana Power Company's rate structure. Exhibit 6 reflects current prices which will be utilized in model evaluations. Optimistic forecasts were chosen with the idea that conservative projections will lower the risks associated with the investment decision. Should the installation be feasible at the conservative rates, all increases to prices beyond the forecasts are considered "gravy." Also, should the prices indicate margin savings, the investor needs to merely run simulations to establish the levels at which the projection becomes feasible and then make his decisions based on his willingness to accept risk.

Exhibit 4. National Energy Forecast (annual rates percent change).

Chase Econometrics - Optimistic Forecast

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Fuel Oil and Coal	15.8	9.3	10.1	8.2	9.4	10.2	10.1	9.9	9.9	9.9
Electricity	11.4	11.0	12.4	10.5	9.8	8.3	8.0	8.0	8.1	8.1
Natural Gas	16.0	16.1	14.4	17.4	18.2	14.2	13.2	12.8	12.6	12.3

Chase Econometrics - Pessimestic Forecast

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Fuel Oil and Coal	15.8	9.3	10.1	12.5	13.1	13.2	13.2	13.2	13.2	12.8
Electricity	11.4	11.0	12.4	10.8	10.3	8.9	8.3	8.0	7.8	7.7
Natural Gas	16.0	16.1	14.4	17.5	19.0	15.0	13.5	12.7	12.2	11.9

Exhibit 5. Regional Energy Forecasts.

Electricity

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Montana Power	23.0	10.4	9.0	26.8	23.0	9.7	7.7	7.3	7.7	23.0
Montana Dakota Utilities		62.8[1]	10.0	10.4	10.6	9.6	9.7	9.7	9.7	10.3
Pacific Power & Light[2]	37.0[3]	14.2	12.0	11.2	11.2	11.0	11.0	11.0	11.0	11.0

Natural Gas

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Montana Power[4]		12.4	8.5	13.3	5.7	11.6	8.2	2.7	8.6	9.1
Montana Dakota Utilities		5.8	18.9	17.1	18.6	5.6	8.3	6.2	6.1	5.8

---

[1] Current requested increase before Public Service Commission.

[2] 1980-1990 are based entirely on Data Resource Inc.'s electrical price projections.

[3] Current requested increase.

[4] Approximate, interpolated from supplied graph.

Exhibit 6. Energy Prices.

Type	Current Cost	1980-1990 Annual Escalation Rate
Electricity	\$0.029486/KWH + \$2.67 Base	9 % (14.5%)[1]
Natural Gas	First 45 mcf @ \$3.051/mcf \$4.11/mcf above 45 mcf	14.7% (8.5%)[1]
Fuel Oil	\$1.10[9]/gallon	12.0%
Propane	\$0.66[9]/gallon	---[2]
Coal	\$60.00/ton	12.0%

[1] ( ) based on Montana Power Company's forecast.

[2] No forecast data available.

DISCOUNT RATES

While the fuel costs are the critical factor in the evaluation of the conventional system, the critical assumption to be made in the new investment, that of going solar, is the establishment of a discount rate. The discount rate can be described as the rate of interest used to convert benefits and costs occurring at different times to a common point in time, usually the present.

The selection of the discount rate is significant in that a variation of as little as one percent can make a project economical or uneconomical. As the discount rate increases, the present value of a project becomes smaller. Lower discount rates tend to favor projects with deferred benefits, while higher discount rates favor projects with large cash flows in the first few years. Since most of the benefits of conservation accrue in the future, lower discount rates would be advantageous; however, the opposite holds for higher fuel price escalation rates. Higher fuel prices increase the potential energy savings, thus shortening the payback period and decreasing the risks of uncertainty.

Establishing the discount rate is substantially easier than that of forecasting energy prices. To many, the discount rate can simply be set to the cost of borrowing money and leave it at that. Others tie it to the inflation rate using a general rule of thumb that the cost of borrowing money is usually equal to the rate of inflation plus four percent, which represents the financial industry's fee for administration, assumption of risk, etc. Another method is to set the rate at the level which the government borrows money.

Chase Econometrics forecasts the 1981 Consumer Price Index at 11.4 percent. Thus, based on the rule of thumb mentioned earlier, the discount rate should be set at 11.4% + 4.0% = 15.4%. Chase Econometrics also forecasts the federal fund rate to be 14.79 percent. Current 20 year U.S. Treasury Notes are earning 13.71 percent.

For purposes of model evaluation, the discount rate will be set at 14 percent. Any user should, however, vary the discount rate to see the affect changes can make on project feasibility. Fourteen percent was chosen due to recent reports that the rate of inflation for 1980 has been revised downward and also due to preference for the current cost of U.S. Treasury Notes.

While discount rates reflect the concept that money invested in equipment should be charged an opportunity cost, they should not be substituted for the general rate of escalation due to inflation. Costs of items such as general maintenance and insurance are increased more closely according to the rate of inflation rather than the cost of borrowing money. Chase Econometrics predicts the 1980-1990 compound growth rate to be around 8 percent. Again, this is optimistic and the user should add his feelings to the final rate used in the analysis.

TAX CREDITS

Renewable energy sources received a much favorable reception during the Carter Administration than is expected during President Reagan's term in office. Regardless, however, the current investment credits will remain in effect until the current law expires in 1985. The federal income tax credit for renewable energy sources is 40 percent of the first $10,000.00 investment or up to $4,000.00.

The state income tax credit for investments in solar energy is 5 percent of the first $1,000.00 and 2.5 percent of the next $3,000.00, up to a maximum of $125.00. Any system installed after January 1, 1979 is exempt from property taxes for a period of ten years. The maximum exemption is $20,000.00 in appraised value for residential dwellings. While the state credit appears negligible, the exemption from property taxes could be substantial. However, at this point the real estate market has not shown a measurable preference for solar homes.

SAMPLE PROGRAMS

Two sample programs are included here for the user's benefit. The problems were borrowed from the User's Manuals and modified to fit a residence in Montana. Keep in mind that they are by no means included to test the power of the programs, but rather are chosen as the typical active solar system and included to give the user an overview of the inputs and the outputs of the different program. Following the output will be a brief description of the results.

Example 1 - FCHART Domestic Water Heating System

This example is an analysis of a domestic hot water system for a residence in Billings, Montana. The existing system consists of a 52 gallon electric water heater and supplies 80 gallons of water per day at 140°F. Incoming water temperature to the system is 50°F year around. Tank losses are estimated to be 10,500 BTU/day in a 70°F environment. Since the existing water heater is one year old and in good condition, the solar contractor has proposed to install a solar water heating system consisting of 62 square feet of double glazed selective surface liquid heating collectors and an 80 gallon tank which will preheat incoming water before it is drawn into the existing tank. A fixed flow pump will circulate water through the collectors at a rate of 75 gallons per hour. Freeze protection occurs by draining the collectors when the pump is off. Approximately 25 feet of collector piping will be exposed to outside conditions. The piping is one inch outside diameter (o.d.) copper tubing and will be insulated with a one inch jacket of polyurethane with a PVC cover (thermal conductivity = .012 BTU/ft-hr).

Installed cost is $3,100.00 and is to be paid off on a five year loan at an interest rate of 14 percent. The system is eligible for state and federal alternative energy tax credits and has a useful life of 20 years.

Other relevant parameters are:

Collector:

$F_R U_L$ = .90 BTU/ft^2 - F - hr
$F_R \tau\alpha$ = .73
Incident angle modifies constant = .142 (see Note)
Slope = 60 degrees
Area = 62 square feet
Capacitance rates per unit area = 10 BTU/ft^2 - F - hr
Number of covers = 2

Transfer Device:

Inlet pipe heat load = 1.7 BTU/hr - F
Outlet pipe heat load = 1.7 BTU/hr - F

Storage Tank (preheat):

Capacitance per unit collector area = 10.77 BTU/ft^2 - F
Height to diameter ratio = 1.9
Insulation loss coefficient = .88 BTU/ft^2 - hr - F

Auxillary Tank (existing water tank):

Overall heat load = 6.25 BTU/hr - F
Environmental temperature = Electric

Economics:

System cost = $3,100
Loan down payment = 0%
Term of loan mortgage = 5 years
Interest rate = 14%

Fuel:

Electricity cost = $.029486/KW-Hr ($8.64/MMBTU)
Fuel price inflation = 14.5% per year

Note: The incidence angle modifier K(t) is the ratio of the transmittance-absorptance product at the angle which solar radiation strikes the surface to the transmittance-absorption product at an angle perpendicular to the collector surface. For two cover collectors, this ratio is .94 for all months during the heating season if the collector tilt is within plus or minus 15 degrees of the latitude and within 15 degrees of due south. The constant is developed from the equation on Page 90.

Since the problem requires retrofitting, the first run is for the heat load and costs of the existing hot water heater. The sample run follows with comments added to reflect the rationale of the input when useful to understanding the program. Self explanatory answers are ignored. Only those parameters which require different values from the default case are included.

```
                          FCHART - A DESIGN PROGRAM
   FROM THE SOLAR ENERGY LABORATORY OF THE UNIVERSITY OF WISCONSIN
                         VERSION 4.0   9/11/80

 WOULD YOU LIKE INSTRUCTIONS (YES,NO,QUICK) ?
?YES

   FCHART IS USEFUL FOR THE ANALYSIS AND DESIGN OF ACTIVE SOLAR AND
 HEAT PUMP HEATING SYSTEMS. ACTIVE SOLAR SYSTEMS MAY BE VISUALIZED
 AS SHOWN HERE.

                                                                **********
                                                                *  AUX   *
                                                                **********
                                                                    I
**********    **********    **********    **********    **********
* COLLEC *--->* TRANS  *--->* STORE  *--->* DELIV  *--->*  LOAD  *
**********    **********    **********    **********    **********

 COLLECTED SOLAR ENERGY IS TRANSFERRED TO STORAGE. A DELIVERY DEVICE
 SUPPLIES THIS ENERGY TO THE LOAD, WITH AUXILIARY EQUIPMENT MEETING ANY
 REMAINING ENERGY REQUIREMENT. A SPACE HEATING SYSTEM WITHOUT AN ACTIVE
 COLLECTOR IS CONSIDERED TO COMPRISE SOLELY A LOAD WITH AUXILIARY.
   SINCE A SYSTEM CONSISTS OF A GROUP OF INTERACTING COMPONENTS HAVING
 SPECIFIC CHARACTERISTICS, FCHART REQUIRES YOU TO
     (1) SELECT SYSTEM COMPONENTS BY ANSWERING A SERIES OF QUESTIONS
     (2) SUPPLY VALUES FOR COMPONENT PARAMETERS (OR USE THE DEFAULTS)
 THE SYSTEM DESCRIPTION QUESTIONS BEGIN BY ASKING FOR YOUR GENERAL
 SYSTEM TYPE AND THEN ASK ABOUT SPECIFIC COMPONENTS, PROCEEDING ACROSS
 THE ABOVE FIGURE FROM LEFT TO RIGHT. FOR AN ACTIVE SYSTEM, YOU WILL BE
 ASKED QUESTIONS ABOUT YOUR COLLECTOR, THEN THE METHOD OF ENERGY
 TRANSFER FROM COLLECTOR TO STORE, AND SO ON.
   YOU MAY USE ANY PROGRAM COMMAND AS YOU GO ALONG. HERE ARE A FEW
 COMMANDS TO GET YOU STARTED :
     HELP   - TYPE HELP AT ANY POINT FOR INSTRUCTIONS OR ASSISTANCE
     FORGET - PUTS YOU BACK AT THE TOP OF THE LIST OF QUESTIONS
     DONE   - TERMINATES FCHART SESSION
 REMEMBER, TYPE HELP WHENEVER YOU NEED IT.

   WHICH SYSTEM TYPE WOULD YOU LIKE TO CONSIDER (PROC,SPACE,SDHW,DHW) ?
?DHW

   DO YOU HAVE A FLAT-PLATE, CPC, OR IMAGING COLLECTOR (FPLATE,CPC,IMAGE
?FPLATE

   DO YOU WANT COLLECTOR PIPE OR DUCT LOSS CALCULATIONS (LOSS,NLOSS) ?
?NLOSS

   DO YOU WANT COLLECTOR AIR DUCT LEAK CALCULATIONS (LEAK,NLEAK) ?
?NLEAK

   DO YOU WANT COLLECTOR-STORE HEAT EXCHANGER CALCULATIONS (HX,NHX) ?
?NHX

   WOULD YOU LIKE AN ECONOMIC ANALYSIS (ECON,NOECON) ?
?YES

 INPUT NOT RECOGNIZED -YES
   WOULD YOU LIKE AN ECONOMIC ANALYSIS (ECON,NOECON) ?
?NOECON
```

```
                                                    **********
         SYSTEM TYPE : DHW                          *  AUX   * FUEL
                                                    **********
                                                        I
**********   **********   **********   **********   **********
* COLLEC *-->* TRANS  *-->* STORE  *-->* DELIV  *<--*  LOAD  *
**********   **********   **********   **********   **********
  FPLATE       NLOSS        LIQ
               NLEAK        TANK
               NHX                  ECONOMICS : NOECON


   THIS IS THE SYSTEM YOU HAVE SPECIFIED. EACH OF THE COMPONENTS
 SHOWN ABOVE (E.G. COLLECTOR,LOAD,AUX) HAS A LIST OF PARAMETERS
 ASSOCIATED WITH IT. YOU MAY NOW WISH TO LIST PARAMETERS, CHANGE
 PARAMETERS, OR USE ANY PROGRAM COMMAND.
     (1) LIST PARAMETERS BY TYPING LIST FOLLOWED BY A COMPONENT NAME
        (COLLECTOR,TRANSFER,LOAD,ETC.) OR A PARAMETER NAME (L1,C5,A2,
        ETC.). TYPE LIST ALL TO LIST ALL PARAMETERS FOR YOUR SYSTEM.
     (2) CHANGE PARAMETERS BY TYPING A PARAMETER NAME FOLLOWED BY THE
        VALUE YOU WANT (E.G. C1=50). SOME PARAMETERS, SUCH AS COLLECTOR
        SLOPE AND HOT WATER USE, MAY BE VARIED BY MONTH. FOR THESE
        PARAMETERS, YOU MAY SPECIFY EITHER A SINGLE VALUE FOR ALL
        MONTHS OR 12 SEPARATE VALUES (E.G. L2 = 300,400,250,...,350).
     (3) USE LIST COMMANDS TO GET A LIST OF COMMAND NAMES OR EXPLAIN
        TO GET EXPLANATIONS OF EACH COMMAND. USE RUN FOLLOWED BY A
        LOCATION NUMBER TO RUN AN ANALYSIS AND TYPE DONE TO
        TERMINATE YOUR FCHART SESSION.
   TYPE PROGRAM COMMAND OR PARAMETER NAME AND NEW VALUE. YOU MAY WANT
   TO BEGIN WITH LIST ALL. TRY HELP IF YOU GET CONFUSED.
 ?
?HELP

      TYPE IN PROGRAM COMMAND OR PARAMETER NAME AND NEW VALUE. USE THE
   FOLLOWING COMMANDS FOR MORE INFORMATION :
         LIST COMMANDS - TO GET THE LIST OF COMMANDS
         LIST ALL - TO LIST ALL PARAMETERS
         LIST PGROUPS - TO LIST THE PARAMETER GROUP (COMPONENT) NAMES
         EXPLAIN - TO GET A SHORT EXPLANATION OF EACH COMMAND
```

```
?EXPLAIN

    CHANGE - ALTER DATA OR SYSTEM DESCRIPTION
    CITIES - SELECT WEATHER DATA FOR UP TO 10 CITIES
    DONE   - USER DONE WITH FCHART
    ECON   - ECONOMIC ANALYSIS DESIRED
    ENTER  - ENTER WEATHER DATA FOR NEW LOCATION
    EXPLAIN- EXPLAIN ALL COMMANDS OR COMMAND SPECIFIED
    FLDATA - ENTER FUEL COST DATA.
    FORGET - FORGET SYSTEM DESCRIPTION AND BEGIN ASKING QUESTIONS
    GET    - READ SYSTEM INFORMATION OR DATA FROM FILE
    HELP   - PROVIDE INSTRUCTIONS OR ASSISTANCE
    HPDATA - ENTER HEAT PUMP PERFORMANCE DATA
    KEEP   - WRITE SYSTEM INFORMATION OR DATA TO STORAGE FILE
    LIST   - LIST SYSTEM DESCRIPTION, PARAMETERS, WEATHER DATA, ETC.
    LONG   - ASK LONG SYSTEM DESCRIPTION QUESTIONS
    LOOP   - RUN SEVERAL ANALYSES VARYING PARAMETER GIVEN
    NOECON - NO ECONOMIC ANALYSIS
    OPDATA - ENTER DATA FOR LOOPS AND OPTIMIZATION
    OPTIMZ - OPTIMIZE SYSTEM WITH RESPECT TO GIVEN PARAMETER
    PICTURE- DRAW SYSTEM SCHEMATIC
    QUICK  - ENTER QUICK SYSTEM DESCRIPTION
    RESET  - RESET PARAMETERS TO DEFAULT VALUES
    RUN    - RUN ANALYSIS OF SYSTEM FOR SPECIFIED LOCATION
    SHORT  - ASK SHORT SYSTEM DESCRIPTION QUESTIONS
    TITLE  - PRINT USER-SUPPLIED TITLE AT TOP OF OUTPUT TABLES
    UNITS  - CHANGE FROM ENGLISH UNITS TO SI, OR VICE VERSA

 TYPE EXPLAIN FOLLOWED BY ANY COMMAND NAME FOR MORE INFORMATION
 ?
?UNITS

 ENGLISH UNITS
 ?
```

```
?LIST CITIES (Up to 10 cities can be accessed from mass storage at a time -
              default values listed here.)
CALL NO.      CITY          STATE  LATITUDE

    4      ALBUQUERQUE       NM     35.03
   25      BISMARCK          ND     46.46
   27      BOSTON            MA     42.22
   38      CHARLESTON        SC     32.54
   48      COLUMBIA          MO     38.49
   59      DENVER            CO     39.45
  127      MADISON           WI     43.13
  149      NEW YORK(CEN PK)NY       40.47
  191      SANTA MARIA       CA     34.54
  195      SEATTLE-TACOMA    WA     47.27
 ?
?CITIES 245,246,247,248,249,250   (Six Montana cities and data are loaded from
                                   the file for later use.)
 ?
?LIST CITIES

CALL NO.      CITY          STATE  LATITUDE

  245       ANACONDA         MT     46.12
  246       BILLINGS         MT     45.78
  247       BOZEMAN          MT     45.67
  248       BROWNING         MT     48.55
  249       BUTTE            MT     46.00
  250       CHOTEAU          MT     47.82
 ?
?ECON   (It was decided to run an economic analysis after all.)

 ?
?LIST  COMMANDS


   PROGRAM COMMANDS
       CHANGE    CITIES    DONE      ECON      ENTER     EXPLAIN
       FLDATA    FORGET    GET       HELP      HPDATA    KEEP
       LIST      LONG      LOOP      NOECON    OPDATA    OPTIMIZE
       PICTURE   QUICK     RESET     RUN       SHORT     TITLE
       UNITS
   TYPE EXPLAIN FOR MORE INFORMATION

 ?
?LIST PGROUPS

   PARAMETER GROUPS :
       COLLECTOR    TRANSFER    STORAGE     DELIVERY
       LOAD         AUXILIARY   ECONOMICS
   TO LIST COLLECTOR PARAMETERS, FOR EXAMPLE, TYPE LIST COLL.
 ?
 ?
?LIST FLDATA   (List default energy prices.)


          FUEL COST

ELEC (BLOCK RATE STRUCTURE)
     ANNUAL INFLATION RATE  10.0 %
     BLOCK                  1
     COST ($/MMBTU)         6.3
     MAX. USE (MMBTU) 9477.7
```

9477.7 is an arbitrary limit set to reflect a flat rate of $6.30/ MMBTU ($.02149/KWH)

```
TYPE FLDATA TO ENTER OR CHANGE FUEL COSTS
 ?
?FLDATA


 GAS, ELECTRIC OR OIL ?
?ELECTRIC


 BLOCK RATES OR SEQUENCE OF AVERAGE COSTS (BLOCK,SEQ) ?
?BL   (FCHART accepts abbreviated answers.)


 ANNUAL INFLATION RATE (PER CENT) ?
?14.5  (Montana 1970-80 projected price escalation factor.)

 ENTER COST ($/MMBTU) AND MAX USE (MMBTU) FOR UP TO 5 BLOCKS
?8.64 99999   ($8.64/MMBTU = $.029486/KWH)

 ?
?LIST FLDATA


          FUEL COST

ELEC (BLOCK RATE STRUCTURE)
     ANNUAL INFLATION RATE  14.5 %
     BLOCK                  1
     COST ($/MMBTU)         8.6
     MAX. USE (MMBTU)99999.0
 ?
?LIST COLL  (List default values.)


COLLECTOR PARAMETERS
 C1. COLLECTOR AREA ..............................  538.20 FT2
 C2. FR-UL PRODUCT ...............................     .74 BTU/HR-FT2-DEG
 C3. FR-TAU-ALPHA (NORMAL INCIDENCE) .............     .70
 C6. NUMBER OF COVERS ............................    2.00
 C7. INDEX OF REFRACTION .........................    1.53
 C8. EXTINCTION COEFFICIENT X LENGTH (KL).........     .04
 C9. INCIDENCE ANGLE MODIFIER CONSTANT ...........     .00
 C10. COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA ......    9.69 BTU/HR-FT2-DEG
 C12. COLLECTOR SLOPE ............................   43.00 DEGREES
 C13. COLLECTOR AZIMUTH ..........................     .00 DEGREES
 C14. GROUND REFLECTANCE .........................     .20
 ?
?C1 = 0   (Since existing system is not solar, the collector area
           is zero, thus, not contributing to the energy calculations.)
 ?
?C14 0.0  (No ground reflectance to correspond to Fowlke's data.)

 ?
?LIST STORAGE


STORAGE UNIT PARAMETERS
 S1. TANK CAPACITY/COLLECTOR AREA ..................   17.12 BTU/DEG F-FT2
 S2. STORAGE UNIT HEIGHT/DIAMETER RATIO ............    2.00
 S3. HEAT LOSS COEFFICIENT .........................     .09 BTU/HR-FT2-DEG
 S4. ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB) ..   68.00 DEG F
 S5. HOT WATER AUXILIARY TANK UA ...................    7.58 BTU/HR-DEG F
 S6. HOT WATER AUX TANK ENVIRONMENT TEMPERATURE .....   68.00 DEG F
 ?
?S3 0  (No preheat tank.)

 ?
?S5 6.25

 ?
?S6 70  (Temperature around tank is 70 degrees.)

 ?
?LIST LOAD


LOAD PARAMETERS
 L3. HOT WATER USE .................................   79.26 GALLONS/DAY
 L4. HOT WATER SET TEMPERATURE .....................  140.00 DEG F
 L5. WATER MAINS TEMPERATURE .......................   51.80 DEG F
 ?
?L3 80  (80 gallons per day.)

 ?
?L4 140  (Hot water tank setting is 140 degrees F.)

 ?
 ?
?LIST ECON


ECONOMIC PARAMETERS
 E1. ECONOMIC OUTPUT DETAIL (1,2 OR 3) ...............    2.00
 E2. REFERENCE OR COMPARISON SYSTEM (1 OR 2) .........    1.00
 E3. CALCULATE RATE OF RETURN (YES=1,NO=2) ...........    2.00
 E4. INCOME PRODUCING BUILDING (YES=1,2=NO) ..........    2.00
 E5. DEPRC: STR,LN.=1,DC.BAL.=2,SM-YR-DGT=3,NONE=4 ..    1.00
 E6. CONSIDER FEDERAL TAX CREDITS (YES=1,2=NO) .......    1.00
 E7. LENGTH OF ANALYSIS ..............................   20.00 YEARS
 E8. TAX CREDITABLE SYSTEM BASE COST ................$ 6000.00
 E9. NON-TAX CREDITABLE SYSTEM BASE COST ............$     .00
 E10. ANNUAL INCREASE IN PURCHASED ENERGY DEMAND ....     .00 %/YR
 E11. TERM OF MORTGAGE ..............................   20.00 YEARS
 E12. DOWN PAYMENT (% OF ORIGINAL INVESTMENT) .......   10.00 %
 E13. MORTGAGE ANNUAL INTEREST RATE .................    8.00 %
 E14. RESALE VALUE (% OF ORIGINAL INVESTMENT) .......     .00 %
 E15. ANNUAL NOMINAL (MARKET) DISCOUNT RATE .........    8.00 %
 E16. EXTRA INSUR.,MAINT. IN YEAR 1 (% OF ORIG.INV.)     1.00 %
 E17. ANNUAL % INCREASE IN ABOVE EXPENSES ...........    6.00 %
 E18. EFFECTIVE FEDERAL-STATE INCOME TAX RATE .......   35.00 %
 E19. TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST ..    2.00 %
 E20. ANNUAL % INCREASE IN PROPERTY TAX RATE ........    6.00 %/YR
 E21. STATE CREDIT IN TIER ONE......................    24.00 %
 E22. STATE CREDIT TIER ONE BREAK..................$10000.00
 E23. STATE CREDIT IN TIER TWO......................      .00 %
 E24. STATE CREDIT TIER TWO BREAK..................$10000.00
 E25. USEFUL LIFE FOR DEPREC. PURPOSES ..............   20.00 YEARS
 E26. % OF ST. LINE DEP. RATE (DC. BAL. DEPRC.) .....  150.00 %

 TYPE LIST FLDATA FOR FUEL COSTS
 ?
?E1 3   (Annual economic output flag.)

 ?
?E2 1   (This is a reference system.)

 ?
?E8 0   (No investments required.)

 ?
?E15 14 (Discount rate.)
```

```
 ?
?TITLE EXISTING HOT WATER HEATER(ELECTRIC)

 ?
?RUN 246 LONG   (Run the program for Billings and output monthly
                 thermal performance.)

***************   FCHART  ANALYSIS   (VERSION 4.0)  ***************
 EXISTING HOT WATER HEATER(ELECTRIC)

  BILLINGS       MT       LATITUDE 45.8

                       THERMAL PERFORMANCE

                  HT      TA    HWLOAD     QU     QLOSS  FDHW
               (MMBTU)(DEG-F)(MMBTU)  (MMBTU)(MMBTU)
          JAN    .00    23.0    2.19     .00     .00   .00
          FEB    .00    30.2    1.98     .00     .00   .00
          MAR    .00    35.6    2.19     .00     .00   .00
          APR    .00    46.4    2.12     .00     .00   .00
          MAY    .00    55.4    2.19     .00     .00   .00
          JUN    .00    62.6    2.12     .00     .00   .00
          JUL    .00    71.6    2.19     .00     .00   .00
          AUG    .00    69.8    2.19     .00     .00   .00
          SEP    .00    59.0    2.12     .00     .00   .00
          OCT    .00    50.0    2.19     .00     .00   .00
          NOV    .00    35.6    2.12     .00     .00   .00
          DEC    .00    28.4    2.19     .00     .00   .00
          YR     .00    47.3   25.75     .00     .00   .00

                    PURCHASED ENERGY SUMMARY

                         GAS    ELECTRIC    OIL      TOTAL
          USE (MMBTU)    .00     25.75      .00      25.75
          COST ($)       .00    222.52      .00     222.52

             LIFE CYCLE COST ANALYSIS OF CURRENT SYSTEM

         INITIAL COST OF SYSTEM           $      0.
         DOWN PAYMENT                     $      0.
         TOTAL TAX CREDITS                $      0.
         ANNUAL MORTGAGE PAYMENT          $      0. FOR 20 YEARS
```

```
    ****INFORMATION****   ******SYSTEM COSTS******* *ENERGY* ***INDICATORS****
     END     IN-   COMM                        TAX     NET      NET   PW OF  CUMU-
    OF YR TEREST DEPREC   LOAN MAINT    PROP CREDIT    FUEL    CASH    CASH LATIVE
YR  PRINC   PAID DEDUCT  PAYMT & INS     TAX RESALE    COST    FLOW    FLOW     PW
 0      0      0      0      0     0       0      0       0       0       0      0
 1      0      0      0      0     0       0      0     223     223     195    195
 2      0      0      0      0     0       0      0     255     255     196    391
 3      0      0      0      0     0       0      0     292     292     197    588
 4      0      0      0      0     0       0      0     334     334     198    786
 5      0      0      0      0     0       0      0     382     382     199    985
 6      0      0      0      0     0       0      0     438     438     200   1184
 7      0      0      0      0     0       0      0     501     501     200   1384
 8      0      0      0      0     0       0      0     574     574     201   1586
 9      0      0      0      0     0       0      0     657     657     202   1788
10      0      0      0      0     0       0      0     753     753     203   1991
11      0      0      0      0     0       0      0     862     862     204   2195
12      0      0      0      0     0       0      0     987     987     205   2400
13      0      0      0      0     0       0      0    1130    1130     206   2605
14      0      0      0      0     0       0      0    1294    1294     207   2812
15      0      0      0      0     0       0      0    1481    1481     208   3019
16      0      0      0      0     0       0      0    1696    1696     208   3228
17      0      0      0      0     0       0      0    1942    1942     209   3437
18      0      0      0      0     0       0      0    2224    2224     210   3648
19      0      0      0      0     0       0      0    2546    2546     211   3859
20      0      0      0      0     0       0      0    2915    2915     212   4071
TOTAL          0      0      0      0      0      0   21486   21486    4071
PW OF TOT      0      0      0      0      0      0    4071    4071

                         UNDISCOUNTED  ANNUALIZED  PRESENT WORTH
          ENERGY COST        21486         615         4071
          TOTAL  COST        21486         615         4071
 ?
?
```

The results of the existing water system analysis shows monthly hot water load. The energy summary shows that one can expect to consume 25.75 MMBTU for the first year at a cost of $222.52. The life cycle cost gives a yearly fuel cost each year of the 20 year period. The present worth (PW) analysis discounts the fuel costs back to year 0 dollars. Since our discount rate is 14 percent, the fuel costs over the 20 year period is equal to $4,071.00 in today's dollars. Undiscounted, however, the total amount spent will be $21,486.00.

Now that the existing hot water system has been analyzed and stored in the computer as the reference system, the proposed solar installation can be input. All that is necessary is to change the parameters which describe the new system. By listing each group before modifications are made, FCHART informs us only of those parameters which affect this particular description. Again, for those changes which merit special emphasis, comments have been typed in parentheses.

```
 ?
?CHANGE TRANSFER    (Include exterior pipe losses to loss.)

   LOSS OR NLOSS ?
?LOSS

   LEAK OR NLEAK ?
?NLEAK                 (No ducts.)

   HX OR NHX ?
?NHX                   (No heat exchanger.)


   SYSTEM DESCRIPTION COMPLETE

 ?
?PICTURE



                                                              **********
           SYSTEM TYPE : DHW                                  *  AUX   * FUEL
                                                              **********
                                                                  I
**********   **********   **********   **********   **********
* COLLEC *--->* TRANS  *--->* STORE  *--->* DELIV  *--->*  LOAD  *
**********   **********   **********   **********   **********
  FPLATE        LOSS         LIQ
                NLEAK        TANK
                NHX                        ECONOMICS : ECON

 ?
?LIST COLL


COLLECTOR PARAMETERS
 C1. COLLECTOR AREA ....................................          .00 FT2
 C2. FR-UL PRODUCT .....................................          .74 BTU/HR-FT2-DE
 C3. FR-TAU-ALPHA (NORMAL INCIDENCE) ...................          .70
 C6. NUMBER OF COVERS ..................................         2.00
 C7. INDEX OF REFRACTION ...............................         1.53
 C8. EXTINCTION COEFFICIENT X LENGTH (KL)...............          .04
 C9. INCIDENCE ANGLE MODIFIER CONSTANT .................          .00
 C10. COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA .........         9.69 BTU/HR-FT2-DE
 C12. COLLECTOR SLOPE ..................................        43.00 DEGREES
 C13. COLLECTOR AZIMUTH ................................          .00 DEGREES
 C14. GROUND REFLECTANCE ...............................          .00
 ?
?C1 62

 ?
?C2 .90

 ?
?C3 .73

 ?
?C6 2
```

```
?C9 .142

 ?
?C10 10

 ?
?C12 60

 ?
?C14 0.0   (No horizontal reflection.)

 ?
?LIST TRANSFER


COLLECTOR-STORE TRANSFER PARAMETERS
 T2. UA OF COLLECTOR INLET PIPE OR DUCT .............        .00 BTU/HR-DEG F
 T3. UA OF COLLECTOR OUTLET PIPE OR DUCT ............        .00 BTU/HR-DEG F
 ?
?T2 1.7

 ?
?T3 1.7

 ?
?LIST STORAGE


STORAGE UNIT PARAMETERS
 S1. TANK CAPACITY/COLLECTOR AREA ...................     17.12 BTU/DEG F-FT2
 S2. STORAGE UNIT HEIGHT/DIAMETER RATIO .............      2.00
 S3. HEAT LOSS COEFFICIENT ..........................       .00 BTU/HR-FT2-DEG
 S4. ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB) ..     68.00 DEG F
 S5. HOT WATER AUXILIARY TANK UA ....................      6.25 BTU/HR-DEG F
 S6. HOT WATER AUX TANK ENVIRONMENT TEMPERATURE .....     70.00 DEG F
 ?
?S1 10.77

 ?
?S2 1.9

 ?
?S3 .88

 ?
?S4 70

 ?
?S5 6.25

 ?
?S6 70

 ?
?LIST DELE\IVERY   (Whoops!  Backspace and edit.)

 PARAMETER GROUP NOT INCLUDED IN CURRENT SYSTEM
 ?
```

```
LOAD PARAMETERS
 L3. HOT WATER USE ....................................    80.00 GALLONS/DAY
 L4. HOT WATER SET TEMPERATURE ........................   140.00 DEG F
 L5. WATER MAINS TEMPERATURE ..........................    50.00 DEG F
?LIST AUX


AUXILIARY PARAMETERS
 A3. HOT WATER AUXILIARY FUEL (1=GAS,2=ELEC,3=OIL) ..      2.
 A4. AUXILIARY WATER HEATER EFFICIENCY ..............      1.00
 ?
?LIST ECON


ECONOMIC PARAMETERS
 E1. ECONOMIC OUTPUT DETAIL (1,2 OR 3) ...............     3.00
 E2. REFERENCE OR COMPARISON SYSTEM (1 OR 2) .........     1.00
 E3. CALCULATE RATE OF RETURN (YES=1,NO=2) ...........     2.00
 E4. INCOME PRODUCING BUILDING (YES=1,2=NO) ..........     2.00
 E5. DEPRC: STR,LN.=1,DC.BAL.=2,SM-YR-DGT=3,NONE=4 ..     1.00
 E6. CONSIDER FEDERAL TAX CREDITS (YES=1,2=NO) .......     1.00
 E7. LENGTH OF ANALYSIS ..............................    20.00 YEARS
 E8. TAX CREDITABLE SYSTEM BASE COST ................$      .00
 E9. NON-TAX CREDITABLE SYSTEM BASE COST ............$      .00
 E10. ANNUAL INCREASE IN PURCHASED ENERGY DEMAND ....      .00 %/YR
 E11. TERM OF MORTGAGE ..............................    20.00 YEARS
 E12. DOWN PAYMENT (% OF ORIGINAL INVESTMENT) .......    10.00 %
 E13. MORTGAGE ANNUAL INTEREST RATE .................     8.00 %
 E14. RESALE VALUE (% OF ORIGINAL INVESTMENT) .......      .00 %
 E15. ANNUAL NOMINAL (MARKET) DISCOUNT RATE .........    14.00 %
 E16. EXTRA INSUR.,MAINT. IN YEAR 1 (% OF ORIG.INV.)      1.00 %
 E17. ANNUAL % INCREASE IN ABOVE EXPENSES ...........     6.00 %
 E18. EFFECTIVE FEDERAL-STATE INCOME TAX RATE .......    35.00 %
 E19. TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST ..     2.00 %
 E20. ANNUAL % INCREASE IN PROPERTY TAX RATE ........     6.00 %/YR
 E21. STATE CREDIT IN TIER ONE.......................    24.00 %
 E22. STATE CREDIT TIER ONE BREAK...................$10000.00
 E23. STATE CREDIT IN TIER TWO.......................      .00 %
 E24. STATE CREDIT TIER TWO BREAK...................$10000.00
 E25. USEFUL LIFE FOR DEPREC. PURPOSES ..............    20.00 YEARS
 E26. % OF ST. LINE DEP. RATE (DC. BAL. DEPRC.) .....   150.00 %

 TYPE LIST FLDATA FOR FUEL COSTS
 ?
?E2 2

 ?
?E3 1

 ?
?E5 4

 ?
?E8 3100
```

```
 ?
?E11  5

 ?
?E12 0

 ?
?E13 14          (14 percent mortgage rate.)

 ?
?E17 8

 ?
?E19 0           (Solar equipment is exempt from property tax.)
 ?
?E20 8   (See section on discount rates.)

 ?
?E21 5    (5 percent of first $1,000.00.)

 ?
?E22 1000  (5 percent of first $1,000.00.)

 ?
?E23 2.5   (2.5 percent on next $3,000.00.)

 ?
?E24 3000  (Wrong value!)

 ?
?E24 4000  (2.5 percent on next $3,000.00.)
```

```
 ?
?TITLE SOLAR HEATER

 ?
?LIST ALL  (Confirm changes.)


COLLECTOR PARAMETERS
 C1. COLLECTOR AREA ...............................    62.00 FT2
 C2. FR-UL PRODUCT ................................      .90 BTU/HR-FT2-DE
 C3. FR-TAU-ALPHA (NORMAL INCIDENCE) ..............      .73
 C6. NUMBER OF COVERS .............................     2.00
 C7. INDEX OF REFRACTION ..........................     1.53
 C8. EXTINCTION COEFFICIENT X LENGTH (KL)..........      .04
 C9. INCIDENCE ANGLE MODIFIER CONSTANT ............      .14
 C10. COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA ....    10.00 BTU/HR-FT2-DE
 C12. COLLECTOR SLOPE .............................    60.00 DEGREES
 C13. COLLECTOR AZIMUTH ...........................      .00 DEGREES
 C14. GROUND REFLECTANCE ..........................      .00

COLLECTOR-STORE TRANSFER PARAMETERS
 T2. UA OF COLLECTOR INLET PIPE OR DUCT ...........     1.70 BTU/HR-DEG F
 T3. UA OF COLLECTOR OUTLET PIPE OR DUCT ..........     1.70 BTU/HR-DEG F

STORAGE UNIT PARAMETERS
 S1. TANK CAPACITY/COLLECTOR AREA .................    10.77 BTU/DEG F-FT2
 S2. STORAGE UNIT HEIGHT/DIAMETER RATIO ...........     1.90
 S3. HEAT LOSS COEFFICIENT ........................      .88 BTU/HR-FT2-DE
 S4. ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB) ..  70.00 DEG F
 S5. HOT WATER AUXILIARY TANK UA ..................     6.25 BTU/HR-DEG F
 S6. HOT WATER AUX TANK ENVIRONMENT TEMPERATURE ...    70.00 DEG F

LOAD PARAMETERS
 L3. HOT WATER USE ................................    80.00 GALLONS/DAY
 L4. HOT WATER SET TEMPERATURE ....................   140.00 DEG F
 L5. WATER MAINS TEMPERATURE ......................    50.00 DEG F

AUXILIARY PARAMETERS
 A3. HOT WATER AUXILIARY FUEL (1=GAS,2=ELEC,3=OIL) ..   2.
 A4. AUXILIARY WATER HEATER EFFICIENCY ............     1.00
```

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ECONOMIC PARAMETERS
 E1. ECONOMIC OUTPUT DETAIL (1,2 OR 3) ..............     3.00
 E2. REFERENCE OR COMPARISON SYSTEM (1 OR 2) ........     2.00
 E3. CALCULATE RATE OF RETURN (YES=1,NO=2) ..........     1.00
 E4. INCOME PRODUCING BUILDING (YES=1,2=NO) .........     2.00
 E5. DEPRC: STR,LN.=1,DC.BAL.=2,SM-YR-DGT=3,NONE=4 ..     4.00
 E6. CONSIDER FEDERAL TAX CREDITS (YES=1,2=NO) ......     1.00
 E7. LENGTH OF ANALYSIS .............................    20.00 YEARS
 E8. TAX CREDITABLE SYSTEM BASE COST ...............$ 3100.00
 E9. NON-TAX CREDITABLE SYSTEM BASE COST ...........$      .00
 E10. ANNUAL INCREASE IN PURCHASED ENERGY DEMAND ....      .00 %/YR
 E11. TERM OF MORTGAGE ..............................     5.00 YEARS
 E12. DOWN PAYMENT (% OF ORIGINAL INVESTMENT) .......      .00 %
 E13. MORTGAGE ANNUAL INTEREST RATE .................    14.00 %
 E14. RESALE VALUE (% OF ORIGINAL INVESTMENT) .......      .00 %
 E15. ANNUAL NOMINAL (MARKET) DISCOUNT RATE .........    14.00 %
 E16. EXTRA INSUR.,MAINT. IN YEAR 1 (% OF ORIG.INV.)      1.00 %
 E17. ANNUAL % INCREASE IN ABOVE EXPENSES ...........     8.00 %
 E18. EFFECTIVE FEDERAL-STATE INCOME TAX RATE .......    35.00 %
 E19. TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST ..      .00 %
 E20. ANNUAL % INCREASE IN PROPERTY TAX RATE ........     8.00 %/YR
 E21. STATE CREDIT IN TIER ONE.......................     5.00 %
 E22. STATE CREDIT TIER ONE BREAK...................$ 1000.00
 E23. STATE CREDIT IN TIER TWO.......................     2.50 %
 E24. STATE CREDIT TIER TWO BREAK...................$ 4000.00
 E25. USEFUL LIFE FOR DEPREC. PURPOSES ..............    20.00 YEARS
 E26. % OF ST. LINE DEP. RATE (DC. BAL. DEPRC.) .....   150.00 %

 TYPE LIST FLDATA FOR FUEL COSTS
 ?
?RUN 246 LONG
```

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***************   FCHART  ANALYSIS   (VERSION 4.0)  ****************

 SOLAR HEATER

  BILLINGS       MT       LATITUDE 45.8

                          THERMAL PERFORMANCE

                HT      TA    HWLOAD      QU     QLOSS  FDHW
             (MMBTU)(DEG-F)(MMBTU)   (MMBTU)(MMBTU)
        JAN    2.01    23.0     2.19      .72       .14   .26
        FEB    2.09    30.2     1.98      .75       .18   .29
        MAR    2.68    35.6     2.19      .96       .25   .32
        APR    2.71    46.4     2.12     1.02       .30   .35
        MAY    2.56    55.4     2.19     1.01       .28   .33
        JUN    2.77    62.6     2.12     1.17       .36   .38
        JUL    2.92    71.6     2.19     1.36       .44   .42
        AUG    2.92    69.8     2.19     1.37       .45   .42
        SEP    3.07    59.0     2.12     1.37       .45   .43
        OCT    2.80    50.0     2.19     1.21       .38   .39
        NOV    2.06    35.6     2.12      .83       .20   .30
        DEC    1.64    28.4     2.19      .67       .12   .25
        YR    30.24    47.3    25.75    12.44      3.56   .34

                       PURCHASED ENERGY SUMMARY

                          GAS     ELECTRIC    OIL       TOTAL
        USE (MMBTU)       .00      16.87      .00      16.87
        COST ($)          .00     145.77      .00     145.77

                 LIFE CYCLE COST ANALYSIS OF CURRENT SYSTEM

       INITIAL COST OF SYSTEM            $   3100.
       DOWN PAYMENT                      $      0.
       TOTAL TAX CREDITS                 $   1343.
       ANNUAL MORTGAGE PAYMENT           $    903. FOR  5 YEARS
```

```
    ****INFORMATION****   ******SYSTEM COSTS******* *ENERGY* ***INDICATORS****
     END       IN-   COMM                            TAX     NET      NET    PW OF  CUMU-
    OF YR  TEREST  DEPREC   LOAN  MAINT      PROP  CREDIT    FUEL     CASH    CASH  LATIVE
YR  PRINC    PAID  DEDUCT  PAYMT  & INS       TAX  RESALE    COST     FLOW    FLOW     PW
 0   3100       0       0      0      0         0    1342       0    -1341   -1341  -1341
 1   2631     434       0    903     31         0     152     146      928     814   -528
 2   2096     368       0    903     33         0     129     167      974     750    221
 3   1487     293       0    903     36         0     103     191     1028     694    915
 4    792     208       0    903     39         0      73     219     1088     644   1559
 5      0     111       0    903     42         0      39     251     1157     601   2160
 6      0       0       0      0     46         0       0     287      332     151   2311
 7      0       0       0      0     49         0       0     328      378     151   2462
 8      0       0       0      0     53         0       0     376      429     150   2613
 9      0       0       0      0     57         0       0     431      488     150   2763
10      0       0       0      0     62         0       0     493      555     150   2912
11      0       0       0      0     67         0       0     565      632     149   3062
12      0       0       0      0     72         0       0     646      719     149   3211
13      0       0       0      0     78         0       0     740      818     149   3360
14      0       0       0      0     84         0       0     848      932     149   3509
15      0       0       0      0     91         0       0     970     1061     149   3658
16      0       0       0      0     98         0       0    1111     1209     149   3806
17      0       0       0      0    106         0       0    1272     1378     149   3955
18      0       0       0      0    115         0       0    1457     1571     149   4103
19      0       0       0      0    124         0       0    1668     1792     149   4252
20      0       0       0      0    134         0       0    1910     2044     149   4401
TOTAL          1414       0   4515   1417         0    1838   14076    18172    4401
PW OF TOT      1042       0   3100    341         0    1708    2667     4401

                          UNDISCOUNTED   ANNUALIZED   PRESENT WORTH
          ENERGY COST        14076           403          2667
          TOTAL  COST        18172           664          4401
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                        COMPARATIVE LIFE CYCLE ECONOMICS

      **REFERENCE SYSTEM*** ***CURRENT SYSTEM**** ******SAVINGS*******
        SYSTEM    ENERGY        SYSTEM    ENERGY
YR       COST      COST          COST      COST       NET   PW OF    CUM.
                                                     SAVE    SAVE      PW
 0          0         0         -1341         0      1343    1342    1342
 1          0       223           782       146      -704    -618     724
 2          0       255           808       167      -719    -553     170
 3          0       292           836       191      -735    -496    -326
 4          0       334           869       219      -753    -445    -772
 5          0       382           906       251      -773    -401   -1174
 6          0       438            46       287       105      48   -1126
 7          0       501            49       328       124      49   -1077
 8          0       574            53       376       145      51   -1026
 9          0       657            57       431       169      52    -974
10          0       753            62       493       198      53    -921
11          0       862            67       565       230      54    -866
12          0       987            72       646       268      56    -810
13          0      1130            78       740       312      57    -754
14          0      1294            84       848       362      58    -696
15          0      1481            91       970       420      59    -637
16          0      1696            98      1111       487      60    -577
17          0      1942           106      1272       564      61    -517
18          0      2224           115      1457       652      62    -455
19          0      2546           124      1668       754      63    -392
20          0      2915           134      1910       872      63    -329
TOTAL       0     21486          4096     14076      3321    -329
PW TOT      0      4071          1735      2667      -329

                        UNDISCOUNTED   ANNUALIZED   PRESENT WORTH
        ENERGY SAVING       7410           211          1404
        TOTAL  SAVING       3321           -49          -329

        CUMULATIVE UNDISC. ENERGY SAVINGS EQUAL INCREASED
        INVESTMENT IN  15 YEARS

        CUMULATIVE UNDISC. NET SAVINGS EQUAL ZERO
        (BREAK EVEN POINT) IN  16 YEARS

        THE DISCOUNTED RATE OF RETURN IS NOT MEANINGFUL DUE TO
        MULTIPLE REVERSALS OF CASH FLOW
?
?
```

Our analysis shows that the solar system will produce 34 percent (FDHW) of the annual hot water load for our residence. For the year, 12.44 MMBTU (QU) are produced from the collector with 3.5 MMBTU (QLOSS) being lost by the equipment and thus not used. The collected energy (QU) minus the system loss (QLOSS) divided by the total hot water load (HWLOAD) is the solar fraction (FDHW). The purchased energy for the year has been reduced by 34 percent to $145.77 from the previous all electric cost of $222.52. The life cycle cost shows that there is $1,343.00 in tax credits from the state and federal governments. The cash flow analysis shows that the present worth of the solar system is $4,401.00. This means that in today's dollars the solar system and the electric auxillary system would require an actual commitment of $4,401.00.

The comparative life cycle economics is the most important portion of the analysis. This compares the solar system with an auxillary electrical backup against the alternative of the electrical heater by itself. The second and third columns reflect the cost of the energy of the electrical heater alone (reference system). The fourth and fifth columns represent the cost profile of the solar system with an auxillary electrical heater (current system). The least three columns reflect the savings of the current system over that of the reference system, converted to today's dollars. The last column is the cumulative present worth of the yearly cash flows.

The bottom line is that this system will not pay for itself when compared against the reference system. In fact, the new system will actually result in a loss. While the energy savings are substantial, they do not offset the capital investment requirements. The amount of $329.00 in today's dollars reflects the principle that installing the system would be the same as giving away $329.00 today. Obviously, no one wants to do this.

The last three items of the printout are practically useless to the analyst. While the present worth analysis is very helpful, the years until the cumulative undiscounted energy savings equal increased investment, the cumulative undiscounted savings equal zero, and the rate of return analysis can be very misleading.

The years until undiscounted energy savings equal increased investment is a questionable indicator. It tells us that the energy savings equals $3,100.00 after 15 years. Although this indicates that the total cost of the system is negated by energy savings after 15 years, it does not include the costs of interest, operation, maintenance, insurance, and additional property taxes.

The cumulative undiscounted net savings equal zero indicator is a little better because it includes the cost of the current system. It does not, however, reflect the cost of borrowing money (interest) and should be used with discretion.

The last indicator is the internal rate of return. This rate is calculated to reflect the market discount rate which would bring the cumulative net cash flow to zero in the last year. The rate can then be compared against alternative investment plans, i.e., money market funds, stocks, etc. If the rate is greater, the solar investment should be made. The internal rate of return cannot be calculated when the sign of the yearly net cash flows changes. The problem has positive flow in the first year, negative in the next five years, and then positive again. Were the tax credit removed, the change would occur only once in the sixth year. Since tax credits are available in most all solar applications, the internal rate of return analysis is very limited. An alternative could be an external rate of return analysis which allows for changes in cash flow.

Since the system proved unsatisfactory for the present parameters, it was decided to optimize the collector area to see if another size would be more cost effective. The cost of the collector ($3,100.00) reflects a base price of $1,600.00 plus a cost of $25.00 per square feet of collector.

Based on this cost parameter, E8 was changed to $1,600.00 and the optimization routine was implemented. C1 is the variable being allowed to vary and two data points were set up to reflect intermediate costs. Straight interpolation between the two points added to the base price will produce the collector costs. The data points 0,0 and 200,5000 provide a large enough range to interpolate between.

reflects the principle that installing the system would be the same as giving away $329.00 today. Obviously, no one wants to do this.

The last three items of the printout are practically useless to the analyst. While the present worth analysis is very helpful, the years until the cumulative undiscounted energy savings equal increased investment, the cumulative undiscounted savings equal zero, and the rate of return analysis can be very misleading.

The years until undiscounted energy savings equal increased investment is a questionable indicator. It tells us that the energy savings equals $3,100.00 after 15 years. Although this indicates that the total cost of the system is negated by energy savings after 15 years, it does not include the costs of interest, operation, maintenance, insurance, and additional property taxes.

The cumulative undiscounted net savings equal zero indicator is a little better because it includes the cost of the current system. It does not, however, reflect the cost of borrowing money (interest) and should be used with discretion.

The last indicator is the internal rate of return. This rate is calculated to reflect the market discount rate which would bring the cumulative net cash flow to zero in the last year. The rate can then be compared against alternative investment plans, i.e., money market funds, stocks, etc. If the rate is greater, the solar investment should be made. The internal rate of return cannot be calculated when the sign of the yearly net cash flows changes. The problem has positive flow in the first year, negative in the next five years, and then positive again. Were the tax credit removed, the change would occur only once in the sixth year. Since tax credits are available in most all solar applications, the internal rate of return analysis is very limited. An alternative could be an external rate of return analysis which allows for changes in cash flow.

Since the system proved unsatisfactory for the present parameters, it was decided to optimize the collector area to see if another size would be more cost effective. The cost of the collector ($3,100.00) reflects a base price of $1,600.00 plus a cost of $25.00 per square feet of collector.

Based on this cost parameter, E8 was changed to $1,600.00 and the optimization routine was implemented. C1 is the variable being allowed to vary and two data points were set up to reflect intermediate costs. Straight interpolation between the two points added to the base price will produce the collector costs. The data points 0,0 and 200,5000 provide a large enough range to interpolate between.

```
 ?
?E8 1600

 ?
?OPDATA


 INDEPENDENT VARIABLE ?
?C1


 DEPENDENT VARIABLES (UP TO 5) ?
?NONE


 NUMBER OF DATA POINTS (2 TO 5) ?
?2


 ENTER 2 DATA POINTS
?0,0 200,5000


 COST ELIGIBLE FOR TAX CREDITS (YES,NO)?
?YES

 ?
?LIST OPDATA C1


 INDEPENDENT VARIABLE C 1

 DATA POINTS
            0.000E+00  0.000E+00
            2.000E+02  5.000E+03
 ?
?TITLE COLLECTOR AREA RUN

 ?
?OPT C1

 ?
?RUN 246 LONG
```

The results produced an optimal collector area of 41 square feet which will minimize the present worth of -\$309.00. The solar contribution is smaller (.28 solar fraction) however.

Other analyses were run varying the inflation rate and the slope of the collector without producing a feasible system. Lowering the rate to 12 percent improved the system slightly and lowering the collector slope also increased the solar fraction and had some improving effect on the present worth.

One word of caution is advisable at this point. Although this particular system did not show cost effectiveness, it by no means is intended to hint that domestic hot water systems will not work in Montana. Each residence and city have different characteristics which must be considered. It is used here as a good example of life cycle analysis as a tool for analyzing two alternatives against each other. Although the new system looks promising in energy savings, retaining the existing system is the better choice.

Example 2 - SOLCOST Residential System

Determine the optimal solar collector area and tilt angle for a residential heating system in Helena, Montana. An all electric system is the reference system as well as the auxillary heat source.

The space heating load is computed with a heat loss coefficient of 7.1 BTU/degree day - square foot. A constant daily hot water load of .09 million BTUs was also specified.

The owner was unable to obtain efficiency rates for the collector, but he does know that the collector is a flat plate, utilizes liquid as a transfer medium, has two covers, and a black painted absorber surface. The installed collector cost is $1,500.00 fixed and $24.00 per square feet of collector. The loan will be financed at 10 percent down, over 10 years, and at 14 percent interest.

The liquid storage system requires 1.5 gallons per square feet at an installed cost of $1.00 per gallon, which corresponds to the typical liquid storage system defaulted in SOLCOST. SOLCOST will vary the collector tilt from the latitude, latitude + 7.5, and latitude + 15. In Helena, these tilt angles will be 47, 54, and 62 degrees. The following output shows the inputs which SOLCOST requires for this system. The reader is referred to Appendix B for the SOLCOST default values. Since an optimization of two parameters produces a large number of pages of output, only the optimal system is included here.

```
WELCOME TO THE SOLCOST CONVERSATIONAL INPUT
      PROGRAM.
  NOTES --
     1) ALL USER COMMANDS MUST BE ENTERED AS
        SINGLE CHARACTER INPUTS.
     2) ALL ARRAYS MUST BE TERMINATED WITH THE
        ASTERISK CHARACTER (*).
     3) A CARRAIGE RETURN BY ITSELF ON ANY INPUT
        WILL CAUSE THE JOB TO HALT.
     4) FOR ARRAYS OF DIMENSION 12, I.E.
        INPUTS WHICH CORRESPOND TO MONTHLY
        VALUES, ONLY ONE VALUE NEED BE ENTERED
        IF ALL VALUES ARE THE SAME

TYPE H(ELP) FOR LIST OF USER COMMANDS-

OTHERWISE INDICATE TYPE OF FILE TO
BE PROCESSED BY ENTERING O(LD) OR N(EW) -
INPUT-
?H


 USER COMMANDS (MUST BE ENTERED AS SINGLE-CHARACTERS)
     H(ELP) - LIST USER INPUT COMMANDS
     D(ISP) - DISPLAY LINE INPUT OPTIONS AND/OR
              DEFAULT VALUES
     G(O)   - DEFAULT VALUES O.K., GO TO NEXT INPUT
     L(IST) - LIST CURRENT USER FILE
     C(URRENT)- SAME AS LIST COMMAND, BUT FOR CURRENT
              LINE NUMBER ONLY.
     P(URGE)- PURGE CURRENT LINE NUMBER FROM OUTPUT
              FILE.
     E(XIT) - SAVE THE USER FILE  AND END
              SESSION

NOTES--
     1. USER FILE LINES ARE NUMBERED SEQUENTIALLY
        BEGINNING WITH 1,  I.E., 1, 2, ETC.  THE LINE
        NUMBERS ARE AUTOMATICALLY RESEQUENCED AS USER
        INPUTS ARE ENTERED.
     2. USER COMMANDS D, G, L, C, H,  OR E MAY BE INPUT
        AT ANY TIME CONSTANTS AND/OR ARRAYS ARE BEING
        ENTERED.
     3. TO FACILITATE INPUT, ONLY ONE ELEMENT OF A MON-
        THLY ARRAY NEED BE ENTERED IF ALL ELEMENTS OF
        THE ARRAY HAVE THE SAME VALUE.
     4. ALL PERCENTAGES ARE TO BE ENTERED AS DECIMAL
        FRACTIONS.

 CAUTION:
    A CARRAIGE RETURN BY ITSELF ON ANY INPUT
    WILL CAUSE THE PROGRAM TO HALT, SAVING THE
    OUTPUT FILE.
    REMEMBER TO END ALL ARRAYS WITH THE ASTERISK
    (*) CHARACTER
```

```
ENTER TYPE OF FILE TO BE PROCESSED (O OR N)
INPUT-
?N


DO YOU WISH TO ENTER A TITLE? (Y OR N)
INPUT-
?Y


ENTER TITLE (UP TO 70 CHARACTERS)
?RESIDENTIAL SOLAR HEATING SYSTEM


TWO INPUT MODES ARE AVAILABLE --
   1) INTERROGATION FOR ALL REQUIRED SOLCOST
      INPUTS.  THIS MODE IS RECOMMENDED FOR ALL
      FIRST TIME USERS.  (ENTER 1)
   2) USER SPECIFIES SOLCOST INPUT LINE NUMBERS.
      (ENTER 2)
   NOTE --
      AFTER COMPLETION OF MODE 1, MODE 2 CAN BE
      ENTERED TO MAKE ADDITIONS AND/OR CORRECTIONS.

ENTER 1 OR 2
INPUT-
?1



      ENTER LINE   1:  (INTEGER ARRAY)
      SOLAR SYSTEM TYPE FLAGS BY MONTH
INPUT-
?D

     SOLAR SYSTEM TYPES AND DEFAULT VALUES
                                                  SYSTEM     COLL.
      TYPE                                      TRANSPORT    INLET
      FLAG                                         EFF.      TEMP.
     (LINE 1)     SOLAR SYSTEM TYPE             (LINE 2)  (LINE 3)
     --------     -----------------             --------  --------
         1     SPACE HEATING WITH LIQUID           0.95      115.
               COLLECTORS, COLL/STOR HX,
               FAN COILS OR AIR DUCT HX
         2     TYPE 1 WITH NO COLL/STOR HX         0.95      105.
         4     SWIMMING POOL SYSTEM                0.95       80.
         5     SPACE COOLING WITH LIQUID           0.60      190.
               COLLECTORS, COLL/STOR HX,
               ABSORPTION COOLER
         6     TYPE 5 WITH NO COLL/STOR HX         0.60      180.
         7     SPACE HEATING WITH AIR              0.95       70.
               COLLECTORS, ROCK BED STORAGE
         8     SERVICE WATER HEATING ONLY,         0.90      120.
               COLL/STOR HX, TWO TANK
               METHOD
         9     SPACE HEATING WITH LIQUID           0.95       60.
               COLLECTORS, COLL/STOR HX,
               HEAT PUMP BETWEEN
               STORAGE AND LOAD
        10     TYPE 9 WITH NO COLL/STOR HX         0.95
```

```
       ENTER LINE    1:   (INTEGER ARRAY)
     SOLAR SYSTEM TYPE FLAGS BY MONTH
INPUT-
?1*

       ENTER LINE    2:   (REAL ARRAY)
     AVG MONTHLY TRANSRORT EFFIC/COP - SOLAR SYSTEM
INPUT-
?G


       ENTER LINE    3:   (REAL ARRAY)
     MONTHLY COLLECTOR INLET TEMP AT DAWN, DEG F
INPUT-
?G


       ENTER LINE    4:   (INTEGER ARRAY)
     REFERENCE SYSTEM FUEL TYPE
INPUT-
?2

INPUT-
?2*


       ENTER LINE    5:   (REAL ARRAY)
     AVG MONTHLY EFFIC/COP - REFERENCE SYSTEM
INPUT-
?G


       ENTER LINE    6:   (INTEGER)
     SOLAR AUXILIARY ENERGY FLAG
INPUT-
?2


       ENTER LINE    7:   (REAL VALUE)
     AUXILIARY FURNACE EFFICIENCY
INPUT-
?G
```

```
      ENTER LINE  10:  (INTEGER)
     COLLECTOR TYPE FLAG
INPUT-
?D

    COLLECTOR TYPES AND EFFICIENCY DATA
      TYPE                                  EFF.      EFF. AT
      FLAG                               INTERCEPT    DT/Q=.5
    (LINE 10)     COLLECTOR TYPE         (LINE 14)   (LINE 15)
    ---------     --------------         ---------   ---------
        1       LIQUID, FLAT PLATE,        0.82         0.24
                1 COVER, PAINT
        2       LIQUID, FLAT PLATE,        0.67         0.30
                2 COVERS, PAINT
        3       LIQUID, FLAT PLATE,        0.70         0.30
                1 COVER, SELECTIVE
        4       LIQUID, FLAT PLATE,        0.67         0.50
                2 COVERS, SELECTIVE
        5       LIQUID, CONCENTRATING      0.71         0.65
        6       LIQUID, TUBULAR ARRAY,     0.62         0.49
                SELECTIVE
        7       AIR, FLAT PLATE,           0.60         0.17
                1 COVER, PAINT
        8       AIR, FLAT PLATE,           0.52         0.21
                2 COVERS, PAINT
       10       LIQUID, TRICKLE TYPE,      0.72         0.01
                1 COVER
       21       USER-DEFINED, LIQUID          USER INPUT
                TYPE                        LINES 14 - 15
       22       USER-DEFINED, EVACUATED       USER INPUT
                TUBE TYPE                      LINE 20
       23       USER-DEFINED, AIR TYPE        USER INPUT
                                            LINES 14 - 15
       24       USER-DEFINED, AIR TYPE        USER INPUT
                                               LINE 19

      ENTER LINE  10:  (INTEGER)
     COLLECTOR TYPE FLAG
INPUT-
?2


      ENTER LINE  11:  (INTEGER)
     COLLECTOR TRACKING FLAG (DEFAULT=FIXED)
INPUT-
?G


      ENTER LINE  12:  (REAL VALUE)
     COLLECTOR AZIMUTH ANGLE
INPUT-
?G


      ENTER LINE  13:  (REAL ARRAY)
     COLLECTOR TILT ANGLES, DEGREES
INPUT-
?G
```

```
        ENTER LINE  16:  (REAL VALUE)
      UPPER LIMIT ON COLLECTOR OUTLET TEMP, DEG F
INPUT-
?G


        ENTER LINE  17:  (REAL VALUE)
      LIQUID STORAGE (GAL/SQ.FT OF COLLECTOR AREA)
INPUT-
?G


        ENTER LINE  21:  (INTEGER)
      FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
INPUT-
?G


        ENTER LINE  23:  (REAL VALUE)
      COLLECTOR MODULE SIZE (SQ. FT.)
INPUT-
?20


        ENTER LINE  24:  (INTEGER)
      FLAG TO INCLUDE LISTING OF SOLCOST WEATHER SITES
        ENTER 1 TO LIST SITES, 0 OTHERWISE (DEFAULT IS 0)
INPUT-
?G


        ENTER LINE  25:  (INTEGER)
      SITE LOCATION CODE
        ENTRY OF ZERO REQUIRES INPUTS FOR LINES
        26, 27, 29, 30, 31, AND EITHER 28 OR 35.
INPUT-
?353


        ENTER LINE  34:  (REAL ARRAY)
      GROUND REFLECTANCE BY MONTH
INPUT-
?0.0*


        ENTER LINE  40:  (INTEGER)
      BUILDING LOAD COMPUTE METHOD FLAG
INPUT-
?2


        ENTER LINE  41:  (INTEGER)
      SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG
INPUT-
?G


        ENTER LINE  42:  (REAL VALUE)
      BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)
INPUT-
```

```
       ENTER LINE  43:  (REAL VALUE)
      BUILDING FLOOR AREA (SQ.FT)
INPUT-
?1500


       ENTER LINE  49:  (REAL VALUE)
      LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
INPUT-
?.09


       ENTER LINE  55:  (REAL VALUE)
      SOLAR SYSTEM FIXED COST, DOLLARS
INPUT-
?1500


       ENTER LINE  56:  (REAL VALUE)
      COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
INPUT-
?24


       ENTER LINE  57:  (REAL VALUE)
      LIQUID STORAGE COST (DOLLARS/GALLON)
INPUT-
?1


       ENTER LINE  59:  (REAL VALUE)
      SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)
INPUT-
?G


       ENTER LINE  60:  (REAL VALUE)
      REFERENCE SYSTEM FIXED COST, DOLLARS
INPUT-
?0.0


       ENTER LINE  61:  (REAL VALUE)
      REF. SYSTEM MAINTENANCE (FRACTION OF INIT. COST)
INPUT-
?G


       ENTER LINE  65:  (INTEGER)
      FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
INPUT-
?1


       ENTER LINE  66:  (REAL ARRAY)
      INCOME TAX CREDIT
INPUT-
?G


       ENTER LINE  67:  (REAL VALUE)
      DISCOUNT RATE, FRACTION
```

```
 INPUT-
 ?.14


        ENTER LINE  68:  (REAL VALUE)
       MORTGAGE INTEREST RATE, PERCENT/YEAR
 INPUT-
 ?.14


        ENTER LINE  69:  (REAL VALUE)
       LOAN TERM, YEARS
 INPUT-
 ?10


        ENTER LINE  70:  (REAL VALUE)
       DOWN PAYMENT (FRACTION OF INITIAL COST)
 INPUT-
 ?.10


        ENTER LINE  71:  (REAL VALUE)
       TERM OF LIFE CYCLE ANALYSIS
 INPUT-
 ?G


        ENTER LINE  72:  (REAL VALUE)
       BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)
 INPUT-
 ?G


        ENTER LINE  73:  (REAL VALUE)
       PROPERTY TAX RATE, FRACTION OF INITIAL COST
 INPUT-
 ?G


        ENTER LINE  74:  (REAL VALUE)
       INCOME TAX RATE, (FRACTION)
 INPUT-
 ?.35


        ENTER LINE  82:  (REAL VALUE)
       INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
 INPUT-
 ?.08


        ENTER LINE  84:  (INTEGER)
       FLAG FOR COLLECTOR OPTIMIZATION OPTION
 INPUT-
 ?G


        ENTER LINE  91:  (REAL ARRAY)
       ENERGY COST SCHEDULE-ELECTRICITY
       ENTER LINE 140:  (INTEGER)
      FLAG TO SKIP INLET TEMP. ITERATIVE PROCEDURE
INPUT-
?G


       ENTER LINE 156:  (REAL VALUE)
      PRE-HEAT (OR STORAGE) TANK INSULATION U-VAL
        (BTU/HR-SQ.FT-DEG F)
INPUT-
?.1


       ENTER LINE 157:  (REAL VALUE)
      AMBIENT TEMP. AT AUX. AND PRE-HEAT TANKS, (F)
INPUT-
?70


       ENTER LINE 169:  (INTEGER)
      FLAG TO UPDATE COLLECTOR PARAMETERS
INPUT-
?G


       ENTER LINE 190:  (INTEGER)
      FLAG TO EXECUTE SUBSYSTEM SELECTION/SIZING ROUTINES
         ENTER 1 TO EXERCISE ROUTINES, OR
         ENTER 0 (OR G) TO SUPRESS THEM. (DEFAULT IS 0)
INPUT-
?G


       ENTER LINE 260:  (INTEGER)
      TOTAL SYSTEMS OPTIMIZATION FLAG
INPUT-
?G


THIS COMPLETES THE LONG FORM OF THE
QUESTIONS. YOU NOW HAVE THE OPTION OF
ENTERING THE SHORT FORM OF QUESTIONING
TO CORRECT ANY ERRORS MADE IN THE LONG
FORM. IN THE SHORT FORM MODE OF QUESTION-
ING YOU MERELY ENTER THE NUMBER OF THE
LINE YOU WISH TO EDIT, AND YOU WILL BE
PROMPTED WITH THE RESPECTIVE QUESTION.

DO YOU WISH TO CHANGE ANY OF
YOUR ANSWERS, BY ENTERING THE
SHORT FORM MODE?
    ANSWER Y OR N --
INPUT-
?N
```

```
INPUT-
?.029486,99999,.145*


DO ELECTRICAL DEMAND CHARGES APPLY?
(YOU MAY WANT TO CONSULT THE MANUAL)
(DEFAULT VALUE IS 'N')
  ENTER Y OR N :
INPUT-
?N


DOES A SUMMER COST SCHEDLUE APPLY
FOR REFERENCE FUEL?
(YOU MAY WANT TO CONSULT THE MANUAL)
(THE DEFAULT VALUE IS 'N')
  ENTER Y OR N :
INPUT-
?N


DOES A SUMMER COST SCHEDULE APPLY
FOR AUXILARY SYSTEM FUEL?
(YOU MAY WANT TO CONSULT THE MANUAL)
(THE DEFAULT VALUE IS 'N')
  ENTER Y OR N :
INPUT-
?N


       ENTER LINE 120:  (INTEGER)
      REFLECTOR ANALYSIS FLAG
INPUT-
?G


       ENTER LINE 130:  (INTEGER)
      EXTENDED PRINT FLAG FOR HOURLY SOLAR FLUXES
INPUT-
?G


       ENTER LINE 131:  (INTEGER)
      PRINTER - PLOTTER FLAG
INPUT-
?1


       ENTER LINE 132:  (INTEGER)
      EXTENDED PRINT FLAG - MONTHLY INSOL. SUMMARY
INPUT-
?1


       ENTER LINE 133:  (INTEGER)
      FLAG TO PRINT INPUTS, LOADS, AND UPDATED PARAMETERS
INPUT-
```

```
RESIDENTIAL SOLAR HEATING SYSTEM
   1,        1        1        1        1        1        1        1        1
             1        1        1        1 *
        $ SOLAR SYSTEM TYPE FLAGS BY MONTH
   4,        2        2        2        2        2        2        2        2
             2        2        2        2 *
        $ REFERENCE SYSTEM FUEL TYPE
   6,        2
        $ SOLAR AUXILIARY ENERGY FLAG
  10,        2
        $ COLLECTOR TYPE FLAG
  23,   .2000E+02
        $ COLLECTOR MODULE SIZE (SQ. FT.)
  25,      353
        $ SITE LOCATION CODE
  34,   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+0
        .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+0
        $ GROUND REFLECTANCE BY MONTH
  40,        2
        $ BUILDING LOAD COMPUTE METHOD FLAG
  42,   .7100E+01
        $ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)
  43,   .1500E+04
        $ BUILDING FLOOR AREA (SQ.FT)
  49,   .9000E-01
        $ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
  55,   .1500E+04
        $ SOLAR SYSTEM FIXED COST, DOLLARS
  56,   .2400E+02
        $ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
  57,   .1000E+01
        $ LIQUID STORAGE COST (DOLLARS/GALLON)
  60,   .0000E+00
        $ REFERENCE SYSTEM FIXED COST, DOLLARS
  65,        1
        $ FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
  67,   .1400E+00
        $ DISCOUNT RATE, FRACTION
  68,   .1400E+00
        $ MORTGAGE INTEREST RATE, PERCENT/YEAR
  69,   .1000E+02
        $ LOAN TERM, YEARS
  70,   .1000E+00
        $ DOWN PAYMENT (FRACTION OF INITIAL COST)
  74,   .3500E+00
        $ INCOME TAX RATE, (FRACTION)
  82,   .8000E-01
        $ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
  91,   .2949E-01   .1000E+06   .1450E+00 *
        $ ENERGY COST SCHEDULE-ELECTRICITY
 131,        1
        $ PRINTER - PLOTTER FLAG
 132,        1
        $ EXTENDED PRINT FLAG - MONTHLY INSOL. SUMMARY
 156,   .1000E+00
        $ PRE-HEAT (OR STORAGE) TANK INSULATION U-VAL
 157,   .7000E+02
        $ AMBIENT TEMP. AT AUX. AND PRE-HEAT TANKS, (F)
RUN
```

```
TITLE:   RESIDENTIAL SOLAR HEATING SYSTEM



----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----


LOCATION --HELENA           MT    LATITUDE = 46.6    TILT ANGLES 46.6 54.1 61.6
LIQUID SOLAR SYSTEM WITH   1.5 GAL. STORAGE PER SQ FT OF COLLECTOR
COL. EFFIC. INTERCEPT =    .67
COL. EFFIC.           =    .30     AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
INPUT SPACE HEAT U-VALUE =  7.10 BTU/(F-DAY-SQ FT)   FLOOR AREA= 1500. SQ FT
INPUT SER. HOT WATER LOAD=   .090 MILLION BTUS/DAY
AUXILIARY ENERGY IS ELECTRIC      LENGTH OF ANALYSIS  20.0 YEARS


                                         SOLAR              REFERENCE
                                         SYSTEM             SYSTEM

INITIAL COST,          $ FIXED          1500.00                 .00
INITIAL COST,          $/SQ FT            24.00               -----
DOWN PAYMENT,          % OF IN. COST      10.0                 10.0
LOAN TERM,             YEARS              10.0                 10.0
INTEREST RATE,         %                  14.0                 14.0
DISCOUNT RATE,         %                  14.0                 14.0
INCOME TAX RATE,       %                  35.0                 35.0
PROP. TAX RATE,        % OF IN COST         .0                   .0
INSURANCE RATE,        % OF IN COST         .5                   .5
MAINTENANCE RATE,      % OF IN COST         .5                   .5
GEN INFLATION,         % PER YEAR          8.0                  8.0



                    JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC

SOLAR SYSTEM TYPE     1    1    1    1    1    1    1    1    1    1    1    1
TRANSPORT EFFIC.    .95  .95  .95  .95  .95  .95  .95  .95  .95  .95  .95  .95
REF. FUEL TYPE     ELEC ELEC ELEC ELEC ELEC ELEC ELEC ELEC ELEC ELEC ELEC ELEC
REF. SYSTEM EFFIC. 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
DAILY LOAD-MIL BTU  .58  .54  .45  .32  .22  .16  .10  .11  .19  .30  .45  .52
MEAN MIN TEMP., F    8.  13.  20.  31.  40.  47.  52.  50.  41.  32.  21.  14.
MEAN MAX TEMP., F   29.  34.  43.  56.  66.  72.  84.  82.  71.  59.  42.  34.
PERCENT POSS. SUN    0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
DAILY HOR. INSOL.  426. 686.1116.1608.1619.1841.1788.1676.1425. 934. 504. 329.
HEATING DEG. DAYS 1438.1170.1042. 651. 381. 195.  31.  59. 294. 601.1002.1265.
SUPPLY WATER , F    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.
ENERGY COST DATA

 ELECTRIC   $ .029 PER UNIT FOR FIRST   .100E+06  UNITS
     ESCALATION RATE =  14.50 PERCENT
```

```
      SOLCOST INSOLATION SUMMARY FOR TILT = 61.6 DEGREES

      AVE. DAILY       CLEAR DAY        AVE. DAILY       CLEAR DAY
      HORIZONTAL       HORIZONTAL       COLLECTOR        COLLECTOR
      INSOLATION       INSOLATION       INSOLATION       INSOLATION
      (BTU/SQ FT)      (BTU/SQ FT)      (BTU/SQ FT)      (BTU/SQ FT)

JAN       425.6            590.5            939.5           1532.2
FEB       686.4            979.5           1170.5           1953.3
MAR      1116.4           1505.8           1431.1           2109.8
APR      1607.7           1983.3           1544.1           1965.2
MAY      1619.0           2328.7           1235.8           1791.3
JUN      1841.3           2450.9           1284.5           1696.0
JUL      1788.2           2325.1           1309.3           1701.1
AUG      1676.5           2012.5           1477.5           1794.3
SEP      1424.7           1564.6           1711.9           1908.8
OCT       934.3           1076.3           1563.1           1870.8
NOV       503.5            669.5           1075.0           1601.3
DEC       329.4            496.4            756.4           1397.4
NOTE: CLEARNESS FACTOR =  1.000


                        SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA     240.    500.    740.    980.   1220.   1460.   1720.   1960.   22
STORAGE SIZE       360.    750.   1110.   1470.   1830.   2190.   2580.   2940.   33
STORAGE COSTS      360.    750.   1110.   1470.   1830.   2190.   2580.   2940.   33
COLLECTOR COSTS   5760.  12000.  17760.  23520.  29280.  35040.  41280.  47040.  528
FIXED COSTS       1500.   1500.   1500.   1500.   1500.   1500.   1500.   1500.   15
                 ------  ------  ------  ------  ------  ------  ------  ------  ---
TOTAL COSTS       7620.  14250.  20370.  26490.  32610.  38730.  45360.  51480.  576
```

```
         SYSTEM PERFORMANCE AND COST SUMMARY FOR  61.6 TILT ANGLE

COLLECTOR  SOLAR      SOLAR    RATE OF     NET PRESENT      LIFETIME COST
AREA       ENERGY     SYSTEM   RETURN      WORTH  OF        SAVINGS
(SQ.FT.)   FRACTION   COST     ON EQUITY   SOLAR SAVINGS    (UNDISCOUNTED)
                        $         %        $ (SEE NOTE 2)        $

    240.     .326      7620.     34.0          1687.          20372.
    500.     .563     14250.     15.9           769.          31672.
    740.     .687     20370.     10.2         -2627.          31847.
    980.     .787     26490.      7.3         -6476.          29626.
   1220.     .859     32610.      5.0        -10868.          24540.
   1460.     .911     38730.      3.1        -15617.          17569.
   1720.     .944     45360.      1.2        -21213.           7636.
   1960.     .975     51480.       .0        -26378.          -1528.
   2200.     .987     57600.       .0        -31804.         -12495.

         ENERGY BALANCE BY MONTH FOR   240.0 SQ. FT. COLLECTOR

MONTH   FRACTION   AVERAGE USEFUL     TOTAL USEFUL    AUXILIARY       CONVENTIO
        BY SOLAR   SOLAR PER DAY      SOLAR ENERGY    ENERGY          SYSTEM EN
 ---               (BTU/DAY-SQ FT)    (MIL BTU/MO)    (MIL BTU/MO)    (MIL BTU/

  1       .124        302.2               2.25           15.86            18.10
  2       .175        389.4               2.62           12.36            14.98
  3       .265        494.8               3.68           10.21            13.89
  4       .401        536.4               3.86            5.77             9.63
  5       .430        395.8               2.94            3.90             6.85
  6       .666        441.6               3.19            1.60             4.78
  7       .992        416.0               3.09             .03             3.12
  8      1.000        459.5               3.42             .00             3.42
  9       .832        674.2               4.85             .98             5.83
 10       .493        608.9               4.53            4.66             9.19
 11       .207        384.6               2.77           10.60            13.37
 12       .109        239.1               1.78           14.48            16.26
          -----                          ------          ------           ------
ANNUAL    .326                           38.98           80.45           119.42


NOTE 1 .... CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
            (I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 .... NET PRESENT WORTH OF SOLAR SAVINGS = RRESENT WORTH OF NET CASH
            FLOWS (FOR A 14.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT
```

```
TITLE:   RESIDENTIAL SOLAR HEATING SYSTEM



COLLECTOR SIZE OPTIMIZATION BY SOLCOST


BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 62. DEGREES IS   240. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVERS, PAINT
FINANCIAL SCENARIO--RESIDENCE

                          $$$  CASH FLOW SUMMARY  $$$

          (A)                (B)       (C)       (D)       (E)       (F)       (G)
YR   FUEL/UTILITY          MAINT.   PROPERTY   ANNUAL     TAX       LOAN    NET CAS
        SAVINGS           +INSUR.     TAX     INTEREST  SAVINGS   PAYMENT    FLOW

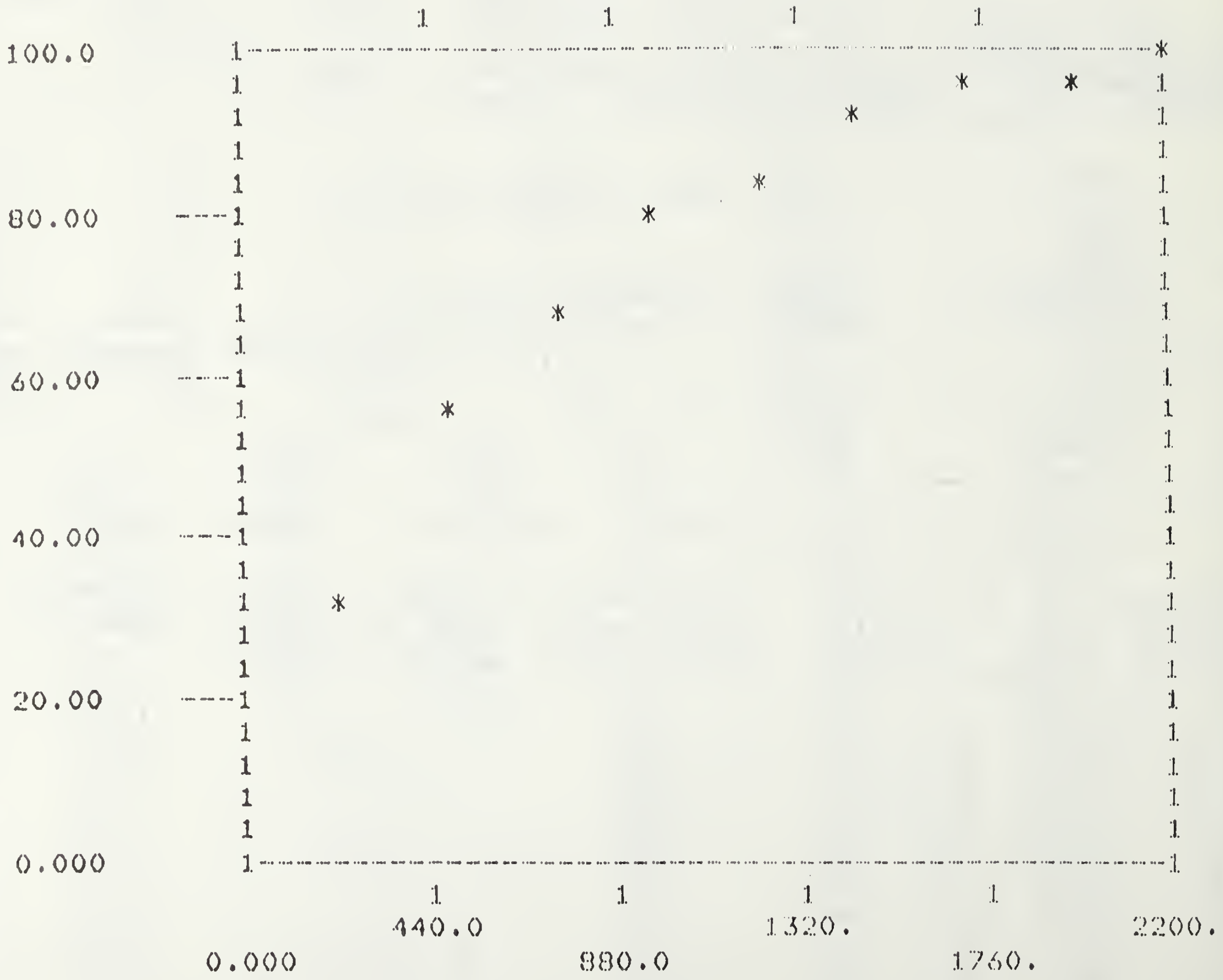
 1       337.               76.        0.       960.     3384.               -762
 2       386.               82.        0.       910.      319.     1315.     2330
 3       442.               89.        0.       854.      299.     1315.     -692
 4       506.               96.        0.       789.      276.     1315.     -662
 5       579.              104.        0.       716.      251.     1315.     -628
 6       663.              112.        0.       632.      221.     1315.     -588
 7       759.              121.        0.       536.      188.     1315.     -542
 8       869.              131.        0.       427.      150.     1315.     -488
 9       995.              141.        0.       303.      106.     1315.     -426
10      1139.              152.        0.       161.       57.     1315.     -354
11      1304.              165.        0.         0.        0.     1315.     -270
12      1494.              178.        0.         0.        0.        0.     1140
13      1710.              192.        0.         0.        0.        0.     1316
14      1958.              207.        0.         0.        0.        0.     1518
15      2242.              224.        0.         0.        0.        0.     1751
16      2567.              242.        0.         0.        0.        0.     2018
17      2939.              261.        0.         0.        0.        0.     2325
18      3366.              282.        0.         0.        0.        0.     2678
19      3854.              304.        0.         0.        0.        0.     3084
20      4412.              329.        0.         0.        0.        0.     3549
                                                                            4083
      ---------          ------     ------    -------   -------    ------    -----
TOTALS  32521.            3488.        0.      6288.     5251.    13150.    20380

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ...   10.7 YEARS
PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT .....   15.0 YEARS
NET PRESENT WORTH OF SOLAR SAVINGS .........               1687.24 DOLLARS
RATE OF RETURN ON NET CASH FLOW ............                  34.5 PERCENT
ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ...                  32.6 PERCENT
ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM ....                  39.0 MILLION BTU

TAX SAVINGS   = INCOME TAX RATE  X (C + D)
NET CASH FLOW = A - B - C + E - F
ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS
```

TITLE: RESIDENTIAL SOLAR HEATING SYSTEM

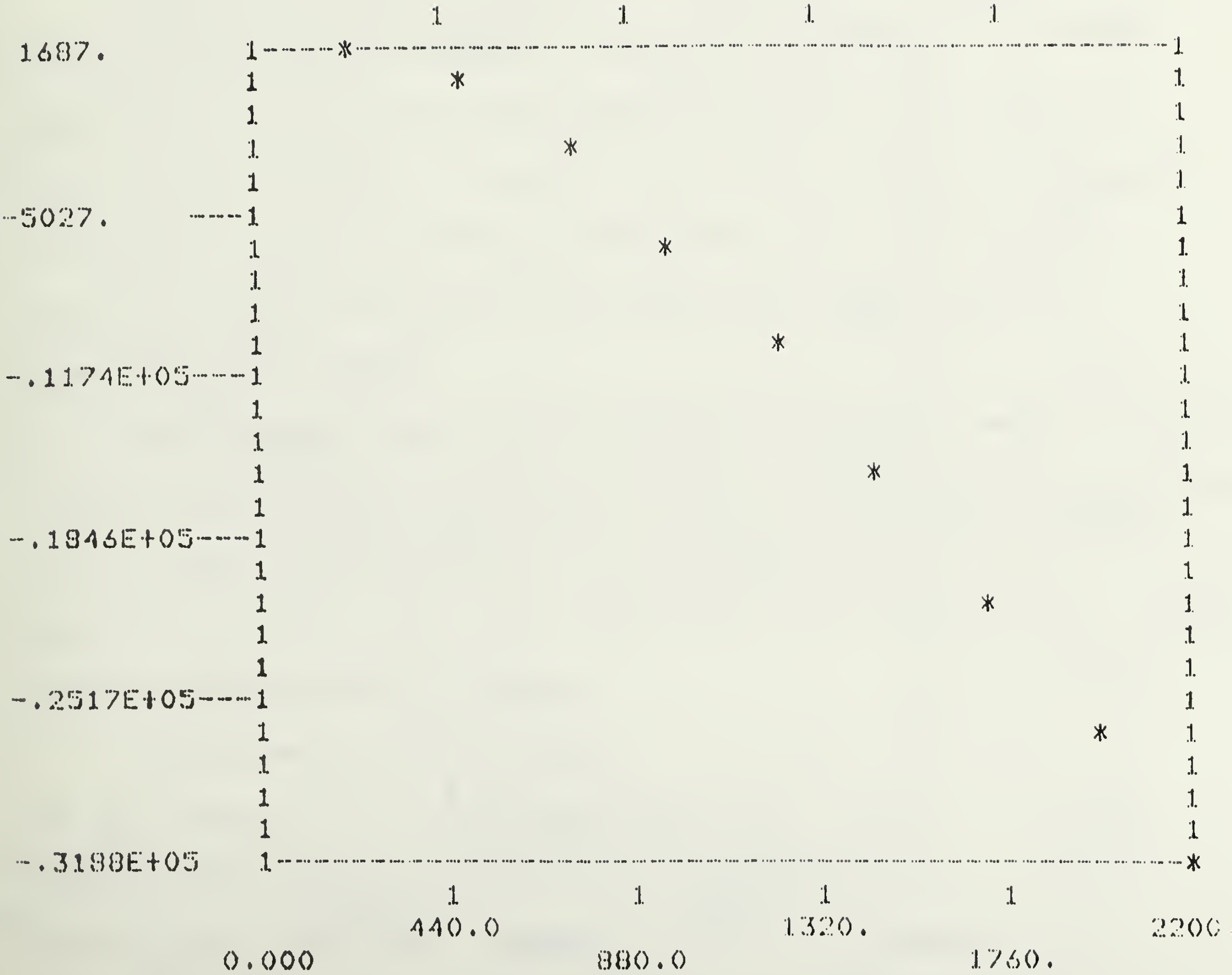
PLOT NUMBER 1



X AXIS IS COLLECTOR AREA (SQ FT)
Y AXIS IS PERCENT SOLAR

TITLE: RESIDENTIAL SOLAR HEATING SYSTEM

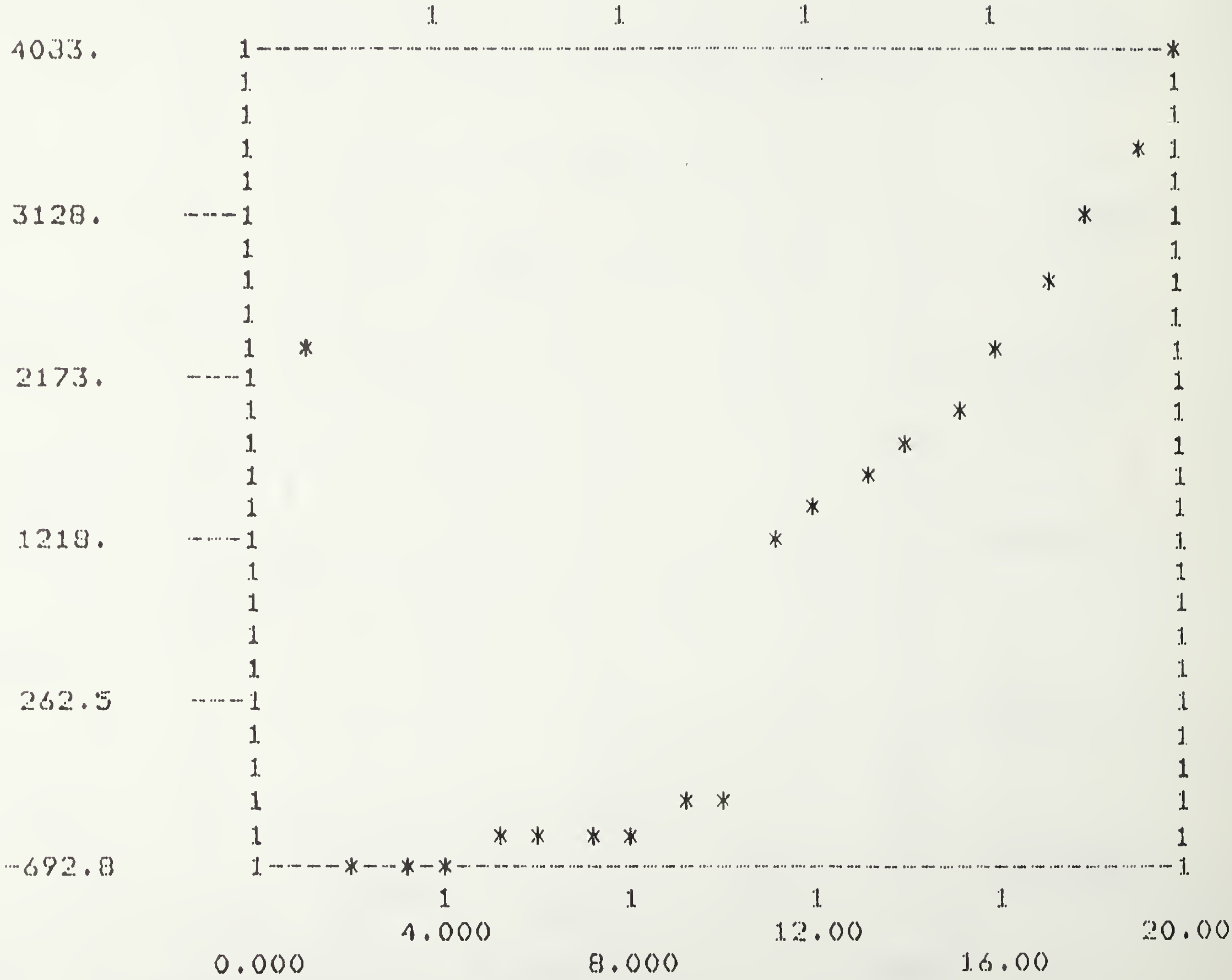
PLOT NUMBER   2



X AXIS IS COLLECTOR AREA (SQ FT)
Y AXIS IS DISCOUNTED SAVINGS FOR LIFE OF SYSTEM

```
TITLE:   RESIDENTIAL SOLAR HEATING SYSTEM


PLOT NUMBER    3
```



```
X AXIS IS LIFE OF SYSTEM (YEARS)
Y AXIS IS SYSTEM CASH FLOW STATUS (DOLLARS)


*STOP*
!
```

The first portion of the printout outlines the system parameters and gives a profile of the horizontal insolation on the collector. The solar system cost summary table outlines the cost parameters of the various collector areas which the model tested.

The system performance and cost summary is for the optimal collector angle, in this case, 61.6 degrees. The various collector areas are then analyzed based on the solar fraction delivered by each, the system costs, rate of return on equity, net present worth of solar savings, and life time cost savings. From this analysis, SOLCOST selects the optimal collector size for this angle (240 square feet) based on the largest positive net present worth of $1,687.00.

This optimal collector size is then used to produce a monthly analysis of solar energy delivered and profiles of the solar energy and auxillary energy for the current system and the cost of the conventional system currently being used to heat the home. The solar fraction (32 percent) indicates that a better collector should probably be explored.

The financial cash flow summary for each year is produced. Again, the best indicator is the present worth analysis. This value, $1,687.00, indicates that installing the solar system would be the same as receiving a check for that amount today. SOLCOST does not have a means for inputting state tax credits unless the federal and state credits were combined into a different series. Assuming this value was received during the first year, its present worth would equal the $110.00 maximum (discounted one year). This can be added to the $1,687.00 to improve the final amount.

Also notice the difference in the approach to the yearly analysis. FCHART applies the tax credit in year 0, while SOLCOST applies the credits during the first year. The inclination is to agree with SOLCOST since tax refunds are not reimbursed instantaneously.

The rate of return analysis and the payback period analysis are again poor indicators as explained in the discussion in the earlier problem.

The plots are an interesting feature of SOLCOST. The first plot gives a profile of the amount of solar energy produced by the various collectors. It also gives insight into the methodology which SOLCOST uses to optimize the area. SOLCOST finds the collector which delivers all of the heat load required and then steps back until the best economic profile is established.

The second plot expresses the collector area in present worth terms and is a repeat of the system cost summary. The third plot outlines the system cash flow throughout the 20 year analysis. The large jump between the 10th and 11th years is due to the loan payoff after 10 years.

CONCLUSIONS

The purpose of this project was to bring to the Renewable Energy Bureau a computer model which it can use in evaluating active solar systems for residences. During discussions of the models, we have strived to present both the positive and negative features of the models. It is understood, however, that the final selection of a model is up to the Renewable Energy Bureau.

The applications of a package such as FCHART or SOLCOST could be very useful to the citizens of Montana. Since the grants program is currently undergoing a self evaluation of its programs, the solar models could be utilized to develop a cost feasibility profile of the different solar systems (residential and commercial). The model could also be used to recommend minimum standards for collectors used in Montana. These two areas could give DNRC an indication of how the active solar industry stacks up in terms of other renewable energy project feasibilities.

Another application of the model is to make the program available to users for the cost of running the program. The neutral party approach could be very well received by the solar industry and the consumers.

One of the features of SOLCOST was very attractive. A very useful application calculates the solar system while including an increased weatherization program. Another feature was the inclusion of a swimming pool heating system. With the current financial stress on municipalities, such a program could be very useful.

Another important point should be emphasized here. While the installation of the models in the computer system was quite expensive and time consuming, the models are fairly straightforward when run. Once the sample problems in the User's Manuals have been followed to familiarize oneself with the format, the analyses become easy. The worksheets supplied with the User's Manuals were utilized and it was found to be quite helpful. It is our feeling that the models can be operated by non-thermal specialists and should be used in the renewable energy grants program.

REFERENCES

REFERENCES

Books and Papers

ASHRAE. 1972. Handbook of Fundamentals - Heating, Refrigerating, Ventilating, and Air Conditioning. Wisconsin: George Banta Co., Inc.

Beckman, William A., Sanford A. Klein, and John A. Duffie. 1977. Solar Heating Design by the f-Chart Method. New York: John Wiley & Sons.

Chase Econometrics. First Quarter, 1981. Long-Term U.S. Macroeconomic Forecast and Analysis, March, 1981.

__________. First Quarter, 1981. Long Term Regional Forecasts, State and Metropolitan Areas, Supplementary Issue.

Dickinson, W.C., and K.C. Brown. August 17, 1979. Economic Analysis of Solar Industrial Process Heat Systems: A Methodology to Determine Annual Required Revenue and Internal Rate of Return. California: Lawrence Livermore Laboratory, University of California.

Doctor, Dr. Ronad D. May 17, 1979. Presented at DOE Consumer Protection Workshop. California Energy Commission.

Fowlkes Engineering. June, 1979. Montana Solar Data Manual. Grant No. RAE 46-Fowlkes 015 and RAE 084-FWLKS-772.

__________. April, 1980. Montana Solar Data Manual Addendum. Grant No. RAE 140-782.

Gaudin, Rob. Winter, 1978. A Site-Specific Economic Analysis of Residential Solar Space Heating. Independent research paper.

International Business Services, Inc. September, 1978. Forecasts for Solar Energy Applications in the United States, 1977-1992. Washington, D.C.

Klein, S.A., and J.C. Theilacker. No date. An Algorithm for Calculating Monthly-Average Radiation on Inclined Surfaces. University of Wisconsin, Solar Energy Laboratory.

Leckie, Jim, Gil Masters, Harry Whitehouse, and Lily Young. 1975. Other Homes and Garbage. California: Sierra Club Books.

McGarity, Arthur E. No date. Solar Heating and Cooling: An Economic Assessment. Washington, D.C.: National Science Foundation.

Mid-American Solar Energy Complex. December, 1979 (revised).
F-Chart Evaluation - The Economic Analysis. By Leonard A. Laulainen, Operations Division, Bloomington, Minnesota.

The Mitre Corporation and Energy Research and Development Administration. 1976.
An Economic Analysis of Solar Water and Space Heating. Contract No. E(49-18)-2322.

Montana Power Company. 1979.
The Montana Power Company 1980-2000 Projections of Electric Loads and Resources.

Montana Department of Natural Resources and Conservation. November, 1980.
The Montana Renewable Energy Handbook. Funded by a U.S. Department of Energy Solar Planning Grant #EG77-01-4099.

Morrison, James W. 1979.
The Montana Energy Saving Handbook for Homeowners. New York: Harper & Row Publishers.

Newkirk, Herbert W. March 29, 1976.
Flat-Plate Solar Collector Handbook - A Survey of Principles, Technical Data and Evaluation Results. California: Lawrence Livermore Laboratory, University of California.

New York State Energy Office. February, 1980.
Solar Workbook.

Palmiter, Larry. 1979.
Development of an Effective Solar Fraction. Presented at the ISES Silver Jubilee Congress - 1979, Joint Meeting with the American Section of ISES, May 28 - June 1, 1979, Atlanta, Georgia.

__________. 1979.
Passive, Active, and Conservation: An Energetic and Economic Analysis. Presented at the ISES Silver Jubilee Congress - 1979, Joint Meeting with the American Section of ISES, May 28 - June 1, 1979, Atlanta, Georgia.

Solar Energy Design Corporation of America. 1978.

Solar Environmental Engineering Company. October, 1980.
SOLCOST, Solar Energy Design Program for Non-Thermal Specialists.

U.S. Department of Energy. July, 1980.
Environmental Data for Sites in the National Solar Data Network. Solar/0010-80-07.

__________. April, 1979.
SOLCOST (Version 2.0). Solar Energy Design Program for Non-Thermal Specialists. Market Development and Training Program, Washington, D.C.

U.S. Department of Energy. July, 1978.
SOLCOST, Space Heating Handbook with Service Hot Water and Heat Loads Calculations. Solar Technology Transfer Program, Washington, D.C.

U.S. Energy Research and Development Administration. June, 1977.
SOLCOST. Solar Hot Water Handbook. Division of Solar Energy, Technology Transfer, Washington, D.C.

U.S. Government Printing Office. March 13, 1977.
The Economics of Solar Home Heating. Washington, D.C.

University of Wisconsin, Solar Energy Laboratory. September, 1980.
A Design Program for Solar Heating Systems. EES Report 50, FCHART 4.0.

Western SUN. No date.
Montana Solar and Weather Information. WSUN/#8.

White, John A., Marvin H. Agee, and Kenneth E. Case. 1977.
Principles of Engineering Economic Analysis. New York: John Wiley & Sons.

Correspondence and Personal Communication

Fowlkes Engineering. June 9, 1981.
Letter and solar data.

Great Falls Gas Company. February 24, 1981.
Letter to Mr. Dan Elliott, Montana Public Service Commission.

McClintock Corporation. July, 1981.
Letter and abstract on solar F-Chart and economic analysis.

__________. March 18, 1981.
Personal communication with Mr. Robert McClintock.

Montana-Dakota Utilities Company. February 27, 1981.
Letter to Montana Public Service Commission.

Montana Power Company. March, 1981.
The Montana Power Company Forecast of Electricity and Natural Gas Prices, 1981-1990, presented to Montana Public Service Commission.

Pacific Power & Light Company. March 2, 1981.
Letter to Mr. Dan Elliott, Montana Public Service Commission.

Quinn, Bob. July 13, 1981.
Personal communication.

Solar Environmental Engineering Company. March 11, 1981.
Letter from David J. Guenther, Systems Analyst.

University of Wisconsin, Solar Energy Laboratory. September 10, 1980.
Letter to FCHART users and worksheets.

Periodicals

Industrial Engineering. March, 1980.
Volume 12, No. 3.

Solar Age. July, 1981.

Western Wildlands. Fall and Winter, 1978-79.
Solar Economics (and Ethics) by David J. Spear. Volume 5, No. 2.

APPENDIX A

FCHART INPUT PARAMETERS AND DEFAULT VALUES

FCHART INPUT PARAMETERS AND DEFAULT VALUES

The following parameter descriptions with the default system values penciled in were reproduced from the FCHART User's Manual. The reference to specific chapters are references to those chapters in the User's Manual. It is suggested that the reader refer to the User's Manual if further explanations are desired.

Collector Parameters

C1. COLLECTOR AREA 538.2 FT2

The total collector aperture area used in your system. The same area (gross or net) as used in determining C2 and C3 should be supplied here.

C2. FR-UL PRODUCT .... .74 BTU/HR-FT2-DEG

If collector performance data is plotted as collector efficiency versus (Tin - Tamb)/I, a straight line will usually fit the data points well. FR-UL, the product of the heat removal factor FR and the overall loss coefficient UL, is the negative of the slope of this line. A collector test procedure for determining FR-UL and FR-TAU-ALPHA is described in ASHRAE Standard 93-77. FR-UL is assumed to be based on aperture area.

If the data is plotted with either the outlet temperature or the average temperature in place of inlet temperature, then it is necessary to calculate FR-UL and FR-TAU-ALPHA (C2 and C3) as described in Chapter 10 of the third section of this manual. The data used to construct the plot of efficiency vs. (Tin-Tamb)/I must be taken using the same collector flow rate as is expected in the installation. For liquid heating solar collectors, data taken at different flowrates may be modified as outlined in Chapter 10.

C3. FR-TAU-ALPHA (NORMAL INCIDENCE) .... .70

The collector heat removal factor FR times the transmittance-absorptance product TAU-ALPHA (also called optical efficiency) is the y-intercept of the straight line efficiency plot described above.

C4. CONCENTRATION RATIO 2.00

The ratio of collector aperture area to absorber area. Used for CPC's and imaging concentrators only.

C5. CPC ACCEPTANCE HALF-ANGLE .... 30 DEGREES

CPC collectors accept all radiation incident within the acceptance half-angle of the optical axis.

C6. NUMBER OF COVERS 2

Number of transparent covers over the collector absorber. Parameters C6 through C8 are used to estimate incidence angle effects unless a non-zero incidence angle modifier constant (parameter C9) is supplied.

C7. INDEX OF REFRACTION 1.53

For glass covers, use 1.526.

C8. EXTINCTION COEFFICIENT * LENGTH .... .04

Product of the extinction coefficient of the cover material and the thickness of each cover.

C9. INCIDENCE ANGLE MODIFIER CONSTANT .... .00

The incidence angle modifier K(t) is the transmittance-absorptance product at incidence angle t divided by the transmittance-absorptance product at normal incidence. Parameter C9, the incidence angle modifier constant, is the number b which provides the best fit in the equation

$$K(t) = 1. - b(1./\cos(t) - 1.)$$

If a value of b of zero is specified, parameters C6 - C8 are used to consider incidence angle effects.

C10. COLLECTOR FLOW RATE * SPECIFIC HEAT/AREA ...... 9.69 BTU/HR-FT2-DEG F

Collector capacitance rate per unit area. In air-based systems, this parameter is used to correct for variations in storage stratification. In systems with collector-storage heat exchangers, it is used to account for heat exchanger effects.

C11. TRACKING AXIS (1=EW, 2=NS, 3=2-AXIS) 3.00

Three tracking modes are available for imaging collectors: east-west axis, north-south axis, and dual-axis tracking.

C12. COLLECTOR SLOPE .... 43 DEGREES

The angle between the plane of the collector aperture and the ground (horizontal) (may have 12 monthly values).

C13. COLLECTOR AZIMUTH .... 0.0 DEGREES

The deviation of the normal to the collector surface from the local meridian; the zero point directly facing the equator, west positive, and east negative. At present (Version 4.0), only zero azimuth collectors may be used for liquid-based systems.

C14. GROUND REFLECTANCE .... .20

Reflectance of horizontal surface in front of collector. This is used to estimate the total solar radiation incident on flat-plate collectors (may have 12 monthly values).

C15. INCIDENCE ANGLE MODIFIERS (10,20,30,40,50,60,70,80 DEGREES)

Incidence modifiers for the plane which passes through the collector axis and is normal to the collector aperture.

1.0 .99 .98 .95 .90 .80 .63 .37

Collector-Store Transfer Parameters

T1. EPS-CMIN OF COLLECTOR-STORE HX/COLLECTOR AREA .. 9.69 BTU/HR-FT2-F

Effectiveness of collector-store heat exchanger times the minimum of the two capacitance rates (mass flow rate times specific heat) through the heat exchanger, divided by collector area. In air-based combined space and water heating systems, this parameter refers to the heat exchanger from the collector outlet duct to the water preheat tank.

T2. UA OF COLLECTOR INLET PIPE OR DUCT .... 0.0 BTU/HR-FT2 DEG

Overall loss coefficient U of inlet pipe or duct multiplied by surface area A.

T3. UA OF COLLECTOR OUTLET PIPE OR DUCT ....0.0 BTU/HR-FT2-DEG F

Overall loss coefficient U of outlet pipe or duct multiplied by surface area A.

T4. COLLECTOR DUCT LEAK RATE (PER CENT) 15.0

Percent of collector outlet duct flowrate which is leakage. The collector is assumed to be under negative pressure, i.e. all leaks are into the ducts rather than out.

T5. DUCT LEAK LOCATION (1=INLET,2=OUTLET,3=BOTH) ... 3.0

The total leakage may be assumed to occur in the inlet duct, the outlet duct, or may be evenly distributed between the two ducts.

Storage Unit Parameters

S1. TANK CAPACITY/COLLECTOR AREA .... 17.12 BTU/DEG F-

Tank energy storage capacity per unit collector area (storage mass times specific heat divided by collector area). For liquid based combined space and water heating systems, this is the capacity of the space heating tank plus the capacity of the domestic water preheat tank if one is used. When two tanks are to be accounted for, parameters S2 and S3 must be set so that the correct tank UA will be calculated. For air-based combined space and water heating, this is the capacity of the water preheat tank.

S2. STORAGE UNIT HEIGHT/DIAMETER RATIO 2.0
Ratio of height of tank referred to by parameter S1 to tank diameter.

S3. HEAT LOSS COEFFICIENT .... .09 BTu/HR-FT2 -DEG F
Overall loss coefficient of tank referred to by parameter S1.

S4. ENVIRONMENT TEMPERATURE (-1000 FOR TENV=TAMB) .. 68 DEGREES
Temperature to which tank losses occur. If -1000 is specified, the environment temperature is set equal to the average monthly ambient temperature.

S5. HOT WATER AUXILIARY TANK UA .... 7.5 BTu/HR-DEG F
Overall loss coefficient U times surface area A of hot water auxiliary tank. The auxiliary tank temperature is assumed to be the hot water set temperature (parameter L4).

S6. HOT WATER AUX TANK ENVIRONMENT TEMPERATURE ..... 68.0 DEG F
Temperature to which auxiliary tank losses occur.

S7. ROCK BED CAPACITY/COLLECTOR AREA .... 17.2 BTu/DEG F-FT2
Energy storage capacity (mass times specific heat) of rock bed per unit collector area.

S8. PHASE CHANGE VOLUME/COLLECTOR AREA (X1000)......... 246.07 FT3/FT2
Volume of phase change unit divided by collector area times one thousand. The volume of phase change material is the phase change unit volume times one minus the void fraction (parameter S10).

S9. PHASE-CHANGE MATERIAL DENSITY 91.15 LB/FT3
Density of the phase-change material used in the storage device (not the average density of the storage device).

S10. VOID FRACTION .... .25
Fraction of the phase-change unit volume which does not contain phase-change material.

S11. SOLID PHASE SPECIFIC HEAT .... .46 BTu/LB-DEG F
The specific heat of the phase change material when it is in solid phase.

S12. LIQUID PHASE SPECIFIC HEAT .... .78 BTu/LB-DEG F
The specific heat of the phase change material when it is in liquid phase.

S13. HEAT OF MELTING .... 107.9 BTu/LB
Energy absorbed by melting of unit mass of phase-change material.

S14. MELTING TEMPERATURE .... 89.6 DEG F

Temperature at which phase-change material melts.

Delivery Device Parameters

D1. EPS-CMIN OF LOAD HEAT EXCHANGER .... 2274.72 BTU/HR-DEG F

Effectiveness of load heat exchanger times the minimum of the two capacitance rates (mass flow rate times specific heat) through the heat exchanger.

D2. MINIMUM TEMPERATURE FOR HX OPERATION .... 68 DEGREES

Minimum storage temperature for operation of load heat exchanger pump and fan.

D3. DELIVERY HEAT PUMP NUMBER 2.0

Heat pump performance data is indexed by "heat pump numbers" (see Chapter 8). This parameter is the number corresponding to the performance data for the heat pump which delivers heat from storage to the load.

D4. MINIMUM HEAT PUMP ABSORBER TEMPERATURE .... 50.00 DEG F

Minimum storage temperature (heat pump absorber temperature) required for heat pump operation.

D5. HEAT PUMP BYPASS TEMPERATURE .... 104.0 DEG F

Maximum storage temperature for heat pump operation. When storage is above this temperature, heat is delivered through the load heat exchanger and the heat pump is bypassed.

Load Parameters

L1. BUILDING UA .... 521.29 BTU/HR-DEG F

Overall building loss coefficient U times exterior surface area A. The total building load for a month is the UA times the monthly degree days (based on 18.3 deg. C. (65 deg. F.) base temperature). Degree days may be listed using LIST DATA or LIST DDAYS and entered or changed using ENTER or CHANGE.

L2. ROOM TEMPERATURE .... 68 DEGREES

The temperature of the unheated air entering the load heat exchanger.

L3. HOT WATER USE .... 79.26 gal/day

Total average daily mass demand (total mass demand for month divided by number of days in month).

L4. HOT WATER SET TEMPERATURE .... 140.00 DEG F

Desired temperature of heated water. This temperature is used to calculate total water heating loads and also effects the auxiliary tank heat losses (see parameter S5 description).

L5. WATER MAINS TEMPERATURE .... 51.8 DEG F

Temperature of cold water supplied to water heating system.

L6. TOTAL PROCESS OR SPACE HEATING LOAD .... 473,90 MBTu /DAY

Total average daily energy demand.

L7. HOURS PER DAY 24.00

Number of hours per day that the load operates. It is assumed that the time distribution of the load is not significant. Only the monthly capacitance rate (hourly capacitance rate times hours of operation over the month) is considered in the analysis

L8. LOAD RETURN TEMPERATURE .... 69.8 DEG F

Load heat exchanger cold side inlet temperature; the temperature of the fluid returned from the load to the heat exchanger.

Auxiliary Parameters

A1. AUXILIARY FUEL TYPE (1=GAS,2=ELEC,3=OIL) 2

The type of fuel used for space heating or process heating auxiliary. Use 1 for gas auxiliary, 2 for electric, and 3 for oil. If some other fuel is used, select one of these three and enter the appropriate cost using the command FLDATA. This parameter is used for the purchased energy summary and fuel cost calculations only.

A2. AUXILIARY DEVICE EFFICIENCY 1.0

Average annual auxiliary device efficiency. The total fuel consumption is the total energy demand divided by the consumption efficiency.

A3. HOT WATER AUXILIARY FUEL (1=GAS,2=ELEC,3=OIL) .. 2

Type of fuel used for domestic water heating auxiliary. (See A1 above.)

A4. AUXILIARY WATER HEATER EFFICIENCY 1.0

Average annual auxiliary water heater efficiency. Fuel consumption is energy demand divided by efficiency.

A5. AUXILIARY HEAT PUMP NUMBER 1.0

Heat pump performance data is indexed according to "heat pump number" Set this parameter to the number of the heat pump performance data set which corresponds to the ambient source ("auxiliary") heat pump.

Economic Parameters

E1. ECONOMIC OUTPUT DETAIL (1,2 OR 3) 2.0

Three levels of detail are available for the economic analysis output. Use 1 for short output, 2 for more complete economic indicators, and 3 for annual cash flow summaries.

E2. REFERENCE OR COMPARISON SYSTEM (1 OR 2) 1.0

The "economics package" can be used to determine the life cycle cost of purchasing and operating a system, or for determining costs and savings relative to some reference system. Set this parameter to 1 to get life cycle cost information ("reference system") only. When E2=2, the current system is compared against the most recently run reference system.

E3. CALCULATE RATE OF RETURN (YES=1,NO=2) 2.0

If E3=1, the the rate of return on the current system investment relative to the reference system can be calculated. Set parameter E3 to 2 to avoid this calculation.

E4. INCOME PRODUCING BUILDING (YES=1,2=NO) 2.0

Use 1 for commercial economics, 2 for residential. Commercial buildings have different federal tax credits, income tax deductions, and depreciation deductions.

E5. DEPRC: STR,LN.=1,DC.BAL.=2,SM-YR-DGT=3,NONE=4 .. 1.0

Three types of depreciation for commercial buildings are offered: straight line, declining balance, and sum of the years digits. If E=4, depreciation is not considered.

E6. CONSIDER FEDERAL TAX CREDITS (YES=1,2=NO) 1.0

Set this parameter to 1 to get federal tax credits, use 2 to ignore federal tax credits.

E7. LENGTH OF ANALYSIS .... 20 YEARS

Number of years of "life cycle". The system is assumed to be sold and any remaining mortgage paid off in the final year of the analysis.

E8. TAX CREDITABLE SYSTEM BASE COST $6000.00

In general, some of the system costs will be eligible for tax credits and some will not. In addition, some of the costs result from purchasing components which are being OPTIMIZED or LOOPed while the rest of the initial investment is independent of these components. This parameter should be set to the total system cost which is eligible for tax credits and which is independent of any components OPTIMIZEd or LOOPed.

E9. NON-TAX CREDITABLE SYSTEM BASE COST ....$ 0.00

System cost which is not eligible for tax credits and which is independent of any components on LOOP or OPTIMIZE commands (see E8 above).

E10. ANNUAL INCREASE IN PURCHASED ENERGY DEMAND .... .00 %

Annual per cent increase in demand for purchased energy. Usually this increase is a result of dergradation in solar system performance. Warning: the purchased energy requirement after N years is (1 + E7/100)**N times the first year's requirement. If E7 is 15%, the purchased energy requirement will double in 5 years.

E11. TERM OF MORTGAGE .... 20 YEARS
Length of mortgage (in years). If the system is financed by cash outlay, set E11 to 1 and set E12 to 100.

E12. DOWN PAYMENT (% OF ORIGINAL INVESTMENT) .... 10.00 %
Percent of total system cost which will be paid initially.

E13. MORTGAGE ANNUAL INTEREST RATE .... 8.00 %
Interest rate on mortgage.

E14. RESALE VALUE (% OF ORIGINAL INVESTMENT) .... .00 %
Cash received for resale in final year of analysis as percentage of original system cost. For commercial buildings, the cash received is assumed to be the maximum of the resale value and the value to which the investment has been depreciated.

E15. ANNUAL NOMINAL (MARKET) DISCOUNT RATE .... 8.00 %
The nominal discount rate is the annual rate of return of the best alternative investment. This is the real rate of return plus the general inflation rate. Since extra cash can be used to pay back the mortgage, the minimum rate of return (discount rate) is the mortgage interest rate.

E16. EXTRA INSUR.,MAINT. IN YEAR 1 (% OF ORIG.INV.) 1.00 %
All miscellaneous costs which cannot be entered elsewhere should be included along with insurance and maintenance costs here. Costs are in percent of original investment (total system cost).

E17. ANNUAL % INCREASE IN ABOVE EXPENSES .... 6.00 %
Annual percent increase in insurance, maintenance, and miscellaneous costs covered by parameter E16.

E18. EFFECTIVE FEDERAL-STATE INCOME TAX RATE .... 35.00 %
Since state income tax paid is deductible on federal returns, the effective federal-state income tax rate is

(F + S - (F * S)) * 100

where F and S are the federal and state tax rates, respectively (between 0 and 1; not percent). These tax rates are assumed constant throughout the period of analysis. For states which allow income tax deductions for federal income tax paid, the effective tax rate is

(F + S - 2(F * S))*100/(1 - (F * S))

E19. TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST .. 2.00 %
Since property taxes are paid on assessed value rather than actual cost, the true property tax rate is

(TAX RATE ON ASSESSED VALUE) * (ASSESSED VALUE/SYSTEM COST)

E20. ANNUAL % INCREASE IN PROPERTY TAX RATE .... 6.00 %/year

Annual percent increase in the true property tax rate (supplied as parameter E19).

E21. STATE CREDIT IN TIER ONE........................ 24.00 %

A "two-tier" state tax credit system is assumed. One rate is applied to costs up to some maximum investment and a second rate is applied to additional costs up to a second maximum. The state tax credit received is parameter E21 times the minimum of the system cost and E22, plus E23 times the remaining system cost above E22 but not in excess of E24.

E22. STATE CREDIT TIER ONE BREAK.................... $10000

Maximum investment credited at the rate given by parameter E21.

E23. STATE CREDIT IN TIER TWO....................... .00 %

Tax credit rate on investment in excess of the cost specified for parameter E22.

E24. STATE CREDIT TIER TWO BREAK...................$ 10000.00

Cost above which no additional state tax credit is received (see E21 above).

E25. USEFUL LIFE FOR DEPREC. PURPOSES .... 20 years

The length of time over which the commercial system is to be depreciated to zero value. If this is greater than the length of the analysis (parameter E7), then this value may effect the estimated resale value (see parameter E14 above).

E26. % OF ST. LINE DEP. RATE (DC. BAL. DEPRC.) 150.0%

The federal government allows several rates for writing off investments when the declining balance method is used. These rates are expressed as percentages of the straight line depreciation rate, e.g. set E26 to 200 for "double declining balance" depreciation.

APPENDIX B

SOLCOST INPUT PARAMETERS AND DEFAULT VALUES

SOLCOST INPUT PARAMETERS
AND DEFAULT VALUES

The following parameter descriptions with the default system values were reproduced from the SOLCOST User's Manual. The reference to specific chapters are references to those chapters in the User's Manual. It is suggested that the reader refer to the User's Manaul if further explanations are desired.

Line No.	Input Parameter	Explanation/Options
1	Solar System Type Flag	Array of system type flags by month. Available systems are listed in Table III-1. Can change by month, depending on system design and loads.
2	Solar System Transport Efficiency	Accounts for losses from pipes or ducts.† Table III-1 for defaults. See Appendix G.
3	Collector Inlet Temperature	Minimum daily collector inlet temperature in morning. SOLCOST computes inlet temperature rise through the day. See Table III-1 for defaults. Check Line 16 for allowable outlet temperature.

TABLE III-1. SOLAR SYSTEM TYPES AND DEFAULT VALUES

Type Flag (line 1)	Solar System Type	Transport Efficiency† (Line 2)	Collector Inlet Temperature (Line 3)
1	Space heating with liquid collectors, collector/storage HX, fan coils, or air duct HX	.95	115.
2	Type 1, no collector/storage HX	.95	105.
4	Swimming Pool	.95	80.
5	Space cooling with liquid collectors, absorption cooling	.60	190.
6††	Type 5, no collector/storage HX	.60	180.
7	Space heating with air collectors, rock bed storage	.95	70.
8	Service water heating only, collector/storage HX, two tank method	.90	120.
9††	Series heat pump system, water- storage and the load.	.95	60.
10††	Parallel heat pump system, type 1 system with parallel air-to-air heat pump for auxiliary	.95	50.

---

† Transport efficiency is the fraction: 1. - Pipe Losses/Collected Solar. It does not include the efficiency of solar collection. Appendix G contains a methodology for estimating this factor. Storage tank insulation losses are accounted for separately with line 156.

†† Not validated. attempts to input these systems will result in

Line No.	Input Parameter	Explanation/Options
4	Reference System Fuel Type (see Table III-2)	Reference System is main conventional heating or cooling system.
5	Reference System Efficiency/COP (see Table III-2)	Heating system efficiency or cooling system coefficient of performance.
6	Solar System-Fuel Type for Auxiliary Heating/Cooling.	See Table III-2
7	Solar System-Efficiency/COP for Auxiliary Equipment	Assumed constant through year. See Table III-2 for defaults keyed by Line 6.
8	Net Solar Transmittance of Swimming Pool Surface	Defined by month. See Appendix F.
9	Swimming Pool Surface Area (ft^2)	Used to calculate radiation absorbed by pool surface.

TABLE III-2 COMBUSTION/USAGE EFFICIENCY FOR FUEL TYPES FOR REFERENCE OR AUXILIARY SYSTEMS

Lines 4 & 6	Fuel/ Utility	Space Heating Efficiency	Service Water Heating Efficiency[+]	Space Cooling COP[++]
1	Natural gas	.7	.63	.45
2	Electricity	1.0	.90	2.50
3	Fuel Oil	.65	.59	.45
4	LP Gas	.70	.63	.45
5	Coal	.65	.59	.45

[+] For Line 1 = 8

[++] For Line 1 = 5 or 6

Line No.	Input Parameter	Explanation/Options
10	Collector Type Flag (see Table III-3)	Entry of 1 through 10 causes SOLCOST to internally supply the defaulted efficiencies listed in Table III-3. If the user enters a 21 through 24 he must enter his own efficiency data as explained in Table III-3. (See note 1, next page)
11	Collector Fixed or Tracking Type Flag (See Note 2 ... next page)	The SOLCOST insolation routine checks this flag to determine which components of the incoming solar radiation can be included in the analysis. Some collectors cannot accept diffuse solar energy, so types 5 through 8 must be specified. Altitude tracking collectors follow the solar altitude angle by month. Allowable options include: 1 = Fixed, beam & diffuse (default) 2 = Azimuth tracking, beam & diffuse 3 = Altitude tracking, beam & diffuse 4 = Full tracking, beam & diffuse 5 = Fixed, beam only

Line No.	Input Parameter	Explanation/Options
		6 = Azimuth tracking, beam only 7 = Altitude tracking, beam only 8 = Full tracking, beam only
12	Collector Azimuth	Defaults to due South = 0.0 degrees, SE = +, SW = -
13	Collector Tile	Defaults to latitude, lat. + 7.5 degrees, & lat. + 15 degrees. Optimum collector size and cash flow sheet will be computed for each tilt angle.
14	Collector Efficiency	Input only if Line 10 = 21 or 23 See Appendix C, expecially if a heat exchanger is present.
15	Collector Efficiency at $\Delta T/q = 0.5^{o}F/(Btu/hr\text{-}ft^2)$	Input only if line 10 = 21 or 23 See Appendix C.
16	Storage Maximum Allowable Temperature	Defaults to 200. ^{o}F. The collector is shut off when this temperature exceeded.

TABLE III-3. COLLECTOR TYPES AND EFFICIENCY DATA

Type Flag			Intercept	$\Delta T/q_i = .5$
1	Liquid, flat plate, 1 cover, paint	Defaulted	.82	.24
2	Liquid, flat plate, 2 covers, paint	Defaulted	.67	.30
3	Liquid, flat plate, 1 cover, selective	Defaulted	.70	.30
4	Liquid, flat plate, 2 covers, selective	Defaulted	.67	.50
5	Liquid concentrating	Defaulted	.71	.65
6	Liquid, evacuated tube type	Defaulted	.62	.49
7	Air, flat plate, 1 cover, paint	Defaulted	.60	.17
8	Air, flat plate, 2 covers, paint	Defualted	.52	.21
10	Liquid, trickle type, 1 cover	Defaulted	.72	.01
21	----User Defined, Liquid Type	User input Lines 14 & 15		
22	----User Defined, Evacuated Tube Type	User input, Line 20		
23	----User Defined, Air Type	User input, Line 14 & 15		
24	----User Defined, Air Type	User input, Line 19		

****NOTES****

1. A flat plate reflector can be evaluated by SOLCOST. See Lines 120-126 for input details.
2. The "azimuth" tracking algorithm assumes rotation about axis located in the plane of the collector at a fixed tilt angle.

Line No.	Input Parameter	Explanations/Options
17	Liquid Storage per Unit Collector Area	SOLCOST computes storage size for each candidate collector area by multiplying the area by this parameter. System performance and installation costs (see Line 57) are affected by this input. Units are gallon/sq. ft. Default is 1.5 gal/sq ft.
18	Rock Bed Storage per Unit Collector Area	Similar to Line 17. Units are pounds/ sq. ft. Default is 50 pounds/sq. ft.
19	Air Collector Efficiency	See Appendix G for input of this efficiency vs. ambient temperature and insolation is known. When efficiency data is known vs. inlet temperature, set Collector Type Flag = 23 and input lines 14 & 15.
20	Evacuated Tubular Collector Efficiency	See Appendix G for input of this efficiency array. Performance of these devices changes with the hour angle of the sun.
21	Flag for Non-Standard Analysis on Input Collector Area	= 0 Causes SOLCOST to determine cost optimum collector area. (Default) = 1 Solar system performance and life cycle cost analysis is computed for candidate collector areas. Monthly performance and cash flow tables are printed for the collector area input on Line 22. = 2 Solar system performance only is computed for candidate collector areas. A monthly performance table is printed for collector area specified on Line 22. = 3 Solar system performance and life cycle cost analysis is computed for the collector area specified on Line 22. (Minimum run time option.)
22	User Input Collector Area	See Line 21. In the optimization mode, this area is the upper limit on collector size for Line 21 = 0. Default value is 1x10^6 sq. ft. SOLCOST internally rounds to the nearest integer multiple of the module size input on Line 23.
23	Modular Collector Area	Area of one collector panel. The candidate system sizes will be multiples of this input. Default value is 20 sq. ft.
24	Print Flag for Data Bank City List	Input a 1 to get a table of cities and location codes for all of the cities in the data bank. SOLCOST will do no further processing.
25	Site Location Number	See Table III-4, (pg. III-23) for listing of cities. Data bank supplies weather and solar data for each site, lines 26 through 33. Use city nearest to installation. See Note 1 next page.

Line No.	Input Parameter	Explanations/Options
26	Site Latitude	Degrees
27	Site Clearness Factor	Each monthly clearness number in solar insolation calculation is multiplied by this parameter. See Appendix A for defaults.
28	Fraction of Possible Sunshine	Fraction of time that solar insolation is greater than a threshold insolation value which corresponds to distinct shadows. Enter as fractions, i.e., .70 is 70%. See Note 2. Ignore this input if line 25 is input.
29	Minimum Daily Average Temperature	Used in collector performance analysis.
30	Maximum Daily Average Temperature	Same as Line 29 explanation.
31	Heating Degree Days (65°F base)	Used in simplified heating loads analysis.
34	Ground Reflectivity	Default is 0.2 corresponding to no-snow conditions. Use 0.7 for snow conditions.
35	Daily Horizontal Insolation	Input Monthly values of average global horizontal insolation, Btu/day-sq. ft. See Note 3.
36	Clearness Number Array	Input monthly values of clearness numbers. See Appendix A for details and listing of default values.

NOTES:

1. If a data bank site location is not used (Line 25 not input) then the following data must be input: Lines 26, 27, 28, 29, 30, 31.
2. Lines 28 (Fraction of Possible Sunshine) is the decimal equivalent of the percent of possible sunshine. Historical records for this measurement are available for approximately 300 cities in the United States.
3. Input of Line 35 (Daily Horizontal Insolation) will cause SOLCOST to ignore the Fraction of Possible Sunshine values input (or defaulted from data bank) on Line 28.

Line No.	Input Parameter	Explanation/Options
40	Space heating/cooling Loads Input or Compute Flag	See Table III-5. If there is no space heating or cooling load, ignore this input.
41	Service Hot water Load Input or Compute Flag	See Table III-5
42	Building Heat Loss	$\text{BHLC} = \frac{\text{Design Heat Loss} \times 24}{(T_{in} - T_{out\ design}) \times A_{floor}}, \ \frac{\text{Btu}}{{}^{o}\text{F-Day-Ft}}$
43	Building Gross Floor Area	Above ground floor area, used with Line 42.
44	ASHRAE STD 90-75 Building Description	Input of this data will cause SOLCOST to compute a space heat loss coefficient assuming the building satisfies ASHRAE Standard 90-75. See Table III-6.
45	Utility Usage Records	For retro-fit installations where building energy consumption is known. See Table III-

TABLE III-5. SPACE HEATING/COOLING AND SERVICE HOT WATER LOADS INPUT OR COMPUTATION METHOD

Line 40 Type Flag	Loads Computed or Input From:	Input Required
2	Input Building Heat Loss Coefficient, H	Lines 42 and 43 (Default)
3	ASHRAE STD 90-75, H	Line 44
4	Utility Usage Records, H	Line 45
5	User Input or Loads by Month H, C, HW	Line 46
Line 41 Type Flag	**Service HW Load From:**	
1	Typical Residential HW Use Pattern, HW	Line 47
2	Utility Usage Records (Summer Only), HW	Line 48
3	User Input HW Load, HW	Line 49 (Default)
4	Daily Water Use, Gallons	Line 154
5	Time dependent load. See Appendix H for further information on loads.	

Line No.	Input Parameter	Explanation/Options
46	User Input Loads by Month	Net daily energy delivered to heating or cooling load. Service and domestic water heating loads can be included in this input; if so, do not enter Lines 41 and 49.
47	Typical Residential HW Use Pattern	SOLCOST estimates hot water load from typical residential use patterns. See Table III-8.
48	Utility Usage Records (Summer Only)	Users can input their summer fuel usage to determine their HW load. See Table III-8.
49	User Input HW Load	Input constant net daily service water load here, millions of Btus/day. Default value is 0.0, ignore Line 41 and 49 if HW load has been combined with space heat load on Line 46.

TABLE III-6. INPUTS FOR ASHRAE STD 90-75 METHOD FOR SPACE HEATING LOAD ARRAY 44

TYPE............. = 1. for a detached one or two-family dwelling.
= 2. for all other residential buildings, 3 stories or less
= 3. for all buildings other than Type 1 or Type 2.

WALL AREA........ = Gross exterior wall area, above grade, sq. ft. (includes windows and doors.)

CEILING AREA..... = Ceiling area, sq. ft.

WINDOW PERIMETER........... = Perimeter (sash crack length) of all windows, ft.

SLIDING GLASS DOOR AREA.... = Area of residential sliding glass doors, sq. ft. (Enter 0.0 if Type 3 building.)

RESIDENTIAL DOOR AREA...... = Area of residential swinging doors, sq. ft. (Enter 0.0 if Type 3 building.)

NON RESIDENTIAL DOOR PERIMETER.. = Perimeter of non-residential swinging, revolving, or sliding doors, ft. (Enter 0.0 for Type 1 and 2 building.)

FLOOR AREA....... = Area of floors over unheated spaces, i.e. crawl spaces, unheated basements, etc., sq. ft. (Enter 0.0 if none.)

SLAB PERIMETER... = Perimeter of slab-on-grade floors, ft. (Enter 0.0 if none.)

RESIDENTIAL EXAMPLE...... = 44 , 1., 1420., 1200., 140., 42., 63., 0.0, 120., 0.0, *

TABLE III-7. HEATING LOAD FROM UTILITY RECORDS (RETRO-FIT BUILDING)

Input Array 45 where:

Fuel Type	From Table III-2, decimal.
Fuel Heat Content	Btus/unit of fuel (unburned) (Enter 1.0 to use default values listed on lines 90-94)
Seasonal Fuel Usage (Space Heating Only)	Quantity of fuel consumed over heating season. Units must be consistent with fuel heat content units. Deduct estimated fuel used for hot water heating.
Seasonal Degree Days	Number of degree days (°F-Day) in heating season. Available from local weather stations or fuel suppliers.
Gross Floor Area	Above ground floor area in building.

```
Examples:  45, 3., 1.0, 1084., 7640., 1500., *      $ User default heat content
           45, 3., 141800., 1084., 7640., 1500., * $ User input heat content
```

TABLE III-8. DOMESTIC HOT WATER LOAD CALCULATION METHODS

Array 47 - Typical Use Pattern Method

Fuel Type	From Table III-2, decimal
Fuel Heat Content	Btus/unit of fuel (unburned) Enter 1.0 to use default values listed on Lines 90-94.
No. of Occupants	Average number of occupants in residence, decimal.
Hot Water Use Schedule	= 1. for light use, integer, (15. gal./person/day) = 2. for average use, (20. gal./person/day) = 3. for heavy use, (30. gal./person/day)
Water Delivery Temperature	= Typically 140°F for houses with dishwashers.

```
Example:  47, 1., 1.0, 5., 2., 135., *   $ Typical Use Method
```

Array 48 - Summer Fuel Consumption Method

Fuel Type	From Table III-2, decimal.
Fuel Heat Content	Btus/unit of fuel (unburned). Enter 1.0 to use default values listed on Lines 90-94.
Fuel Useage	= Average monthly fuel consumption for water heating. Units must be consistent with fuel heat content input.

```
Example:  48, 1., 1.0, 65., *  $ Summer Fuel Method
```

Line No.	Input Parameter	Explanations/Options
55	Solar System Fixed Initial Cost	Input total system fixed costs or increment above reference system costs. Does not include collector costs or storage costs.
56	Solar System Installed Cost per Unit Collector area.	Installed cost per square foot of collector area.
57	Solar System Installed Cost of Liquid Storage.	Installed cost per gallon of water storage for liquid systems.
58	Solar System Installed Cost of Rock Bed Storage.	Installed cost per ton of rock bed storage.
59	Solar System Maintenance Cost	Fraction of initial cost for maintenance each year.
60	Ref. System Initial Installed Cost	Input total cost of reference system that would be installed instead of the solar system.
61	Ref. System Maintenance Cost	See Line 59.
65	Financial Scenario Indicator	Three tax considerations are available: 1 ... Homeowner solar system (Residendial) 2 ... Business owned system 3 ... Non-profit organization owned system, i.e., schools, public buildings.
66	Solar Tax Incentives (Applies to Residential Scenario Only, Business Owner see Line 77)	If applicable, enter Array 66 as follows: 66, Fraction,$,Fraction,$* i.e., 66,.30,2000.,.20,8000., * (Default) means: 30% of first $2000 +20% of next $8000 will be credited against net tax due. Two steps must be input.
67	Discount Rate of Present Worth Analysis	A discount rate is the minimum rate of return which a person (or company) usually realizes from their investments. For homeowners a reasonable discount rate is the interest rate at which they can borrow money for a solar investment.
68	Loan Interest Rate	If there is no loan, i.e., 100% down payment, input a 1.0 down payment fraction and omit Lines 68 and 69.
69	Loan Term	Years
70	Loan Down Payment	For 10% down, enter .10, etc.

Line No.	Input Parameter	Explanations/Options
71	Term of Life Cycle Cost Analysis	Usually this is the expected life of the solar system. It can be different from the loan term. Max. of 30 years allowed.
72	Insurance Rate	Fraction of initial cost each year. Same rate applies to both solar and reference system.
73	Property Tax Rate	Fraction of initial cost each year. If a state or local property tax incentive applies, enter a -1.0 for Line 73, and Enter Line 83.
74	Income Tax Rate	Owner's income tax rate (fraction).
75	Depreciation Method	Applies to BUS scenario only. Options are: 1=SL ... straight line 2=DB ... declining balance
76	DB Multiplier	Multiplier used in declining balance depreciation method. Limited to 1.5 for commercial and industrial buildings and 2.0 for new residential rental property.
77	Investment Tax Credit Rate	Solar tax credit is 10% (Default) Enter 20% for process heating equipment.
78	Additional First Year Depreciation	Allowed for solar systems which are considered business related equipment, i.e., to heat hot water for a manufacturing process, a car wash heater, etc. Usually 20% (enter .20) is allowed, up to a $2000 limit.
79	System Useful Life	The allowable useful life for depreciation purposes. Currently ten years is allowed for building HVAC systems.
80	Storage Tank Useful Life	Same as Line 79, only 22 years is allowable minimum for storage components.
81	Salvage Value Fraction	Salvage value at the end of useful life.
82	Inflation Factor for Maintenance, Insurance, and Property Taxes	Annual escalation of these costs due to inflation. A value of 6% (enter .06) is considered reasonable.
83	Property Tax Rate vs. Time	If your state or county has eliminated (or reduced) property tax rates on solar systems, enter:

Line No.	Input Parameter	Explanations/Options
		83, Rate, First I Years, Rate, Next J Years, * 83, 0., 10., .025 30., * means zero property taxes will be levied for the first ten years, and normal rate of 2.5% will apply for the next 30 years. If Line 83 is input, a -1.0 must be entered in Line 73.
84	Collector Optimization Method Flag	SOLCOST defaults to the net present worth method to compute the cost optimum system size. Enter Line 84=2 to optimize with internal rate of return. Enter Line 84=3 to optimize with undiscounted lifetime savings
90	Natural Gas Cost Schedule (See Note 1 and pages III-7,8 for examples)	Check with local supplier for heat content of delivered natural gas. Default is 100000 Btus/100 cubic feet. In Denver this value is 84000. Escalation rate is on a percent per year basis, entered as a fraction. Escalation should include inflation effect, i.e., if a real price rise of 5% is expected, and inflation is 4%, enter .09 as the escalation.
91	Electricity Cost Schedule (See Note 1)	Enter as dollars/Kw-hr.
92	Fuel Oil Cost Schedule	Enter as dollars/gallon.
93	LP Gas Cost Schedule	Enter as dollars/gallon.
94	Coal Cost Schedule	Enter as dollars/ton.
95	Electricity Demand Cost	If the utility applies demand charges, this schedule must be input and expected demand levels estimated on lines 96, 97, and 98. In Denver, the local utility is charging $6.55 per month for the first Kw and $2.70 per Kw of demand above one Kw. Last entry on Line 95 must be the escalation factor for demand costs.
96	Electrical Demand Level Ref. System	Required if demand charges apply.
97	Electrical Demand Level Solar Auxiliary Furnace	Required if demand charges apply.
98	Electrical Demand Level Solar Assisted Heat Pump	Required if demand charges apply.

Note:

1. Utilities will usually quote their electric and gas rate schedules without including fuel cost and gas cost adjustment factors. The input electric and gas cost schedules must be adjusted to account for these parameters.

Line No.	Input Parameter	Explanations/Options
100	Escalation Table for Natural Gas	Escalation rate vs. time for natural gas. Enter a -1.0 for the escalation factor in Array 90. Entry of Array 90 and Array 100 as in the example: 90, .15,800.,-1. * 100, .08,5.,.06,10.,.09,15., * will cause the natural gas price to be escalated: 8 %/yr for the first 5 years 6 %/yr for the next 10 years 9 %/yr for the next 15 years A maximum of four escalations may be entered in Array 100.
101	Escalation Table for Electricity	See Line 100
102	Escalation Table for Fuel Oil	See Line 100
103	Escalation Table for LP Gas	See Line 100
104	Escalation Table for Coal	See Line 100
106	Summer Fuel Cost Schedule for Reference System	Lines 106 and/or 107 may be entered when fuel or electricity prices vary by season or month. Lines 108 and/or 109 must be entered with integer 1's or 0's to flag the months during which the prices in Lines 106 and 107 apply. For example, a proposed system uses electricity for the solar auxiliary and also for the reference energy source. During the months of April through September, the electric rate is increased by 20%. The following arrays should be entered: 91,.034,100000.,.10,* 106,.0408,100000.,.10,3413.,* 107,.0408,100000.,.10,3413.,* 108,0,0,0,1,1,1,1,1,1,0,0,0,* 109,0,0,0,1,1,1,1,1,1,0,0,0,* Array 91 will be used for the months October through March. Array 106 will be used during the months flagged by 1's in array 108. Array 107 will be used during the months flagged by 1's in array 109. Note that
107	Summer Fuel Cost Schedule for System Solar Auxiliary	
108	Month Flags for Summer Fuel Reference System	
109	Month Flags for Summer Fuel Auxiliary	

Line No.	Input Parameter	Explanations/Options
		the fuel heat content must be entered in arrays 106 and 107. If the user wishes to escalate the summer price schedule with multiple escalation factors, he must enter a -1.0 for the escalation in Line 106 or 107, and also enter: Line 104 to escalate Line 106, Line 108 to escalate Line 107.
120	Reflector Analysis Flag	Enter an integer 1 to access the reflector/collector analysis. Flat plate reflectors with a common edge at the collector base are assumed. The analysis accounts for shadowing of the collector by the reflector at low sun angles. Diffuse and specular reflections are considered in the analysis.
121	Reflector/Collector Common Edge Length	Length in feet of common edge between collector and reflector.
122	Collector Length	Collector length, ft.
123	Reflector Length	Reflector length, ft. ****NOTE: The above dimensions need not be actual, but should indicate the relative sizes of collector and reflector.
124	Reflector/Collector Angle	Angle between the reflector and collector, degrees.
125	Reflector Diffuse	Dimensionless, enter as decimal fraction, i.e. enter .70 as 70% Reflectivity.
126	Reflector Specular Solar Reflectivity	Typical values for common reflector materials

	Diffuse Reflectivity	Specular Reflectivity
Silvered glass	0.	.70-.84
Aluminized acrylic on .025" aluminum	0.	.85
Aluminized teflon on .025" aluminum	0.	.87
Alzak aluminum	0.	.78
White marble, ground	.53	0.
White sand, fine	.59	0.

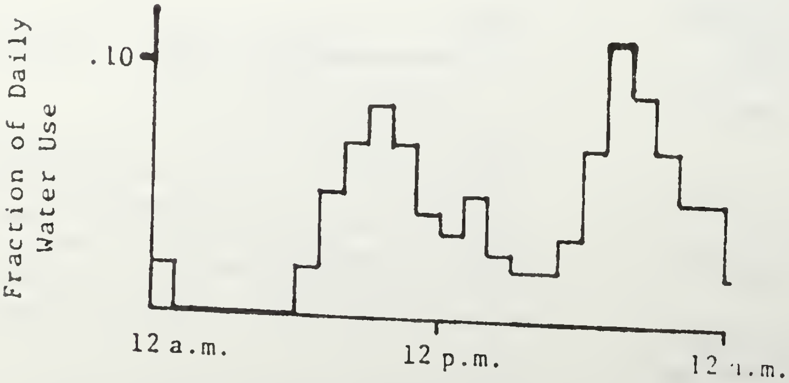
Line No.	Input Parameter	Explanations/Options	Diffuse Reflectivity	Specular Reflectivit
		White sand, course	.50	0.
		Roofing, bituminous felt, aluminized	.60	0.
		Aluminum, as received	0.	.40-.70
		Aluminum, cleaned	0.	.45-.75
		Aluminized Mylar	0.	.75-.85
		****NOTE: The sum of the diffuse and specular reflectivities is the total solar reflectivity for the surface.		
130	Extended Print Flag Hourly Solar Fluxes	Enter an integer 1 to print hourly solar fluxes incident on the collector for each day in the analysis.		
131	Extended Print Flag Printer Plots	Enter an integer 1 to get printer plots for load fraction versus collector area, savings versus collector area and cash flow versus life of system.		
132	Extended Print Flag Insolation Summary	Enter an integer 1 to get a solar insolation summary.		
133	Print Inputs Flag	By entering an integer 1, the inputs will be printed, the loads will be calculated and the weather information will be obtained, but the program will NOT be executed. If this option is exercised, line 134 should be set to 0.		
134	Print Suppression Flag	0 = Print everything (Default) 1 = Print only thermal results 2 = Print only cash flow table 3 = Print only bottom line results, i.e., payback, net present worth, ROR, solar fraction, annual energy savings.		

ITERATIVE DAWN STORAGE TEMPERATURE PROCEDURE

Line No.	Input Parameter	Explanations/Options
140	Flag to Skip Inlet Temperature Iterative Procedure (Integer)	Enter a 0 to skip iterative procedure.
141	Convergence ΔT on Dawn Storage Temperature, °F	Default ΔT provides reasonable speed/accuracy. See Appendix B.
142	Maximum Allowable Number of Iterations (Integer)	If convergence is not achieved before this number of iterations, a warning message is printed.
143	Minimum Allowable Storage Tank Temperature, °F (For Service Hot Water Systems, see line 153)	Lower set point above which useful energy can be supplied to the load. The storage temperature is not allowed to go below this temperature. Ignore for service hot water systems.
145	Flag to Print Monthly Max, Min, Avg Storage Temperatures (Integer)	Enter a 0 (zero) (default) for no output. Enter a 1 to print for optimum or specified collector area only. Enter a 2 to print all candidates.

DETAILED SERVICE (DOMESTIC) WATER SYSTEM INPUTS[+]

Line No.	Input Parameter	Explanations/Options
150	Hourly Hot Water Load Fractions versus Hour of Day (Array of 24 Elements)	Array of 24 fractions which determine the hourly load for that hour from midnight. Default values yield the profile shown in the following figure. $\dot{Q}_i = \text{FRACT}_i * Q_{\text{Daily Load}}$ i = 1, ... and $\sum_{i=1}^{24} \text{FRACT}_i = 1.0$

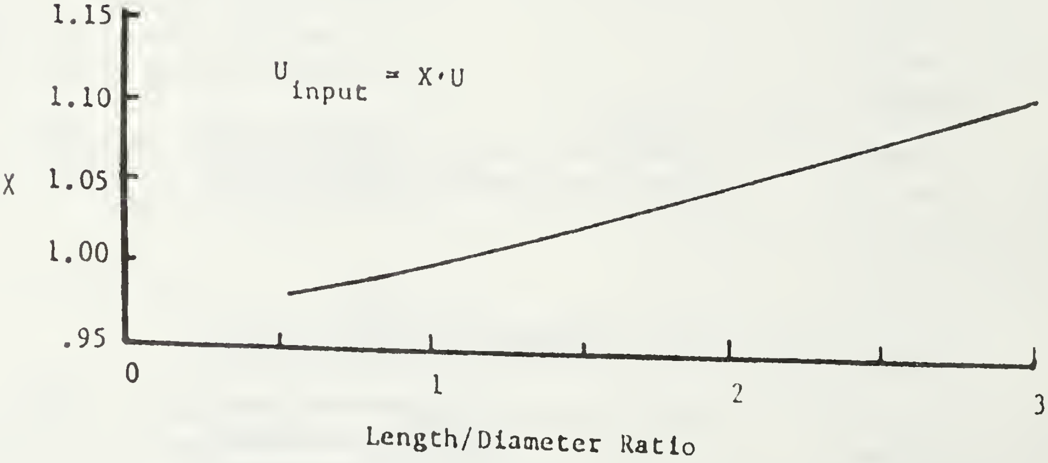


Default Daily Hot Water Load Schedule

[+] The use of mixing (tempering) valves in two-tank service water heating systems is often required by building codes. Version 1.0 of SOLCOST could not evaluate the effect of this component on system performance. Versions 2.0 and later do account for mixing valve effects. See Lines 15 and 152.

Line No.	Input Parameter	Explanations/Options
151	Auxiliary Water Heater Set Temperature, °F	Auxiliary water heater set temperature. Usually this is the delivery temperature, however, when a mixing valve is present, this temperature may be higher than the set point on the mixing valve.
152	Water Delivery (Mixing Valve) Temperature, °F	Delivery (or mixing valve) temperature.
153	Monthly Supply (or Ground) Water Temperatures, °F (Array) See Table III-9 for suggested average soil temperatures.	Array of monthly supply (or ground water) temperatures. The minimum allowable storage tank temperature is internally defaulted to the input monthly supply temperature (Line 153) and Line 143 is ignored. For combined space and service water systems, SOLCOST assumes that the service water is pre-heated in the space heating storage tank.
154	Hot Water Usage, Gal/Day	Hot water usage in gallons per day. Input will cause the hot water load to be computed from: $Q_{\substack{\text{Daily}\\ \text{Load}}} = 8.33\, N_{\text{Gal}}(T_{\text{Del}} - T_{\text{Supply}})$ If this load method is used, Line 41 must be input as an Integer 4. For combined space heating and service water systems, SOLCOST will internally add the hot water load to the space heating load or to the load input in Line 46.
155	Auxiliary Tank UA, Btu/Hr-°F	Auxiliary tank UA. This parameter will not affect the SOLCOST results, since a similar loss is assumed for the alternative conventional system. The magnitude of this loss is printed in the storage temperature summary (Line 145=1).
156	Pre-Heat (or Storage) Tank Insulation U Value, Btu-Hr/ft2-°F	Pre-heat tank insulation U value. Experience has shown that tank insulation losses are often double their expected analytical values. For this reason, users are cautioned to be liberal in their estimate of the insulation U-value. Since the size of this tank is not known beforehand, and because the insulated surface area varies with volume, SOLCOST

Line No.	Input Parameter	Explanations/Options
156 (cont.)		assumes a cylindrical tank with length/diameter ratio equal to one. Hence, the tank area can be expressed as: $A_{tank} = 6\pi\left(\frac{K}{2\pi}\right)^{2/3}\left(A_{col}\right)^{2/3}$ where K = Storage volume/collector area ratio, Ft^3/Ft^2 A_{col} = Collector area, Ft^2 If a given storage tank has an L/D ratio significantly different than one, the user should adjust the input U-value by the factor X given in the following figure.



U-Value Multiplier X for L/D Correction

Line No.	Input Parameter	Explanations/Options
157	Ambient Temperature at Auxiliary and Preheat Tanks, °F	Ambient temperature at auxiliary and preheat tank location. Losses from these tanks are computed from: $Q_{loss} = U\,A\,(T_{tank} - T_{amb})$

Line No.	Input Parameter*	Explanations/Options
169	Flag to Indicate that the Collector Parameters are to be Updated	Input a "1" to execute this option. The SOLCOST program will update the collector parameters which are input with additional information in lines 170 through 189. The resultant efficiencies at 0 and efficiencies at .5 will be included in lines 14 and 15.
170	Flag to Designate that the Input Collector Parameters have been Defined to be a Function of Average Collector Temperature and not Inlet Temperature	Input a "1" to indicate that the collector parameters are to be updated to be a function of inlet temperature not average temperature as input.
171	Mass Capacitance Flow Rate $(\dot{m}c_p)$ per ft^2 of Collector as Tested	Input the mass capacitance flow rate as per square foot of collector area as the collector was tested. Input as Btu/hr-°F-ft^2.
172	Mass Capacitance Flow Rate $(\dot{m}c_p)$ per ft^2 of Collector as Used	Input a mass capacitance flow rate per square foot of collector area as panels are to be used. The SOLCOST progarm assumes a default for liquid (10) and a separate default for air systems (2).
173	$F_R\tau\alpha$ Input for each Collector Path	Input the $F_R\tau\alpha$ for each panel in each path, however, if more than one path is assumed, the user must input line 21 equal to a 3 and input the collector area in line 22.
174	F_RU_L Input for each Collector Path	Input the F_RU_L per panel per path for up to 10 parallel paths. (See line 173)
175	Number of Series Collectors in Each Parallel Path.	SOLCOST assumes that the number of series collector in each path are the same. Remember, that if there is more than one path assumed, line 21 must be equal to a 3 and the collector area must be input on line 22.
176	Number of parallel paths with different parameters or flow rates.	See Line 175.

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* See Appendix E for the Methodology Development.

Line No.	Input Parameter	Explanations/Options
177	Individual Collector Panel Area for each Parallel Path.	This is the collector area of each panel in each parallel path in ft^2. It is the individual panel area.
180	Flag to Indicate that the Collector in Air Systems are Leaky.*	This methodology is accurate only in the neighborhood of where the parameters were derived for the collector area. If the leakage is in excess of 20% this methodology may not work too well.
181	Air Collector Pressure Drop Flag	1 = negative and 2 = positive pressure
182	Leaky Parameters, σ	
183	Leaky Parameters, β	
184	Leaky Parameters, θ	
185	Heat Exchanger Flag	Input a "1" to cause SOLCOST to calculate an F_R'/F_R number to update the collector parameter to reflect the inclusion of a heat exchanger between the collector and storage. Input the effectiveness in line 186.
186	Heat Exchanger Effectiveness	Input between 0 and 1
187	Manifold Conduction Flag	The user may update the collector manifold heat loss conduction by inputting line 187 equal to a "1" and then the inlet and outlet UA's of the inlet and outlet manifolds. The user must input line 21 equal to a "3" to execute this option.
188	UA Inlet Piping/Ducting	
189	Outlet UA of Piping/Ducting	

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*Lines 180-184 are used for situations when the air collector array leaks somewhat. The reader is referred to Appendix C for details of what exactly the individual parameters are. Also, the reader should update the input collector flow rates to reflect what the collectors may actually experience.

SUBSYSTEM COMPONENT SELECTION OPTIONS[+]

Line No.	Input Parameter	Explanations/Options
190	Flag to Execute Subsystem Selection/Sizing Routines (Integer)	Control flag to exercise sizing routines. A liquid system is assumed, unless Line 1 = 7. The default value is 0. Enter a 1 if this feature is desired.
191	Flag for Counterflow Liq-Liq HX in Collection Loop, (Integer)	Flag to size a counterflow liquid-to-liquid heat exchanger in the collection loop. The default value is 0. Enter a 1 if this feature is desired.
192	Flag for Crossflow Air-Liq (or Liq-Air) HX in Collection Loop (or in Load Distribution Loop) (Integer)	Flag to size a crossflow air-to-liquid or a liquid-to-air heat exchanger in the collection loop (or in the load distribution loop). The default value is 0. Enter a 1 if this feature is desired.
193	Flag to Include Components in System Costs for Life Cycle Cost Analysis (Integer)	Flag to include component costs in in life cycle cost analysis. The default value is 0. Enter a 1 if this feature is desired.

LIQUID COLLECTION SUBSYSTEM DESIGN/COST DATA[+]

201	Collector Flow Rate	Collector area dependent volumentric flow rate. Enter as gallons per minute (GPM) per square foot of collector area: usually magnitudes are 0.01 - 0.03.
202	Collector Pressure Drop	The collector pressure drop is usually independent of collector area but very dependent on the collector area dependent flow rate described above. Enter in feet of head loss.
203	Heat Exchanger Pressure Drop (Collection Side)	If a heat exchanger is present in the collection loop enter its expected head loss in feet.
204	Total Pipe or Duct Length in Collection Loop	Enter the total pipe/duct length in the collection loop. SOLCOST uses this length to estimate pipe/duct costs and pumping/blower requirements.

[+] See Appendix D for more details.

Line No.	Input Parameter	Explanations/Options
205	Installed Duct/Pipe Cost per Foot	Enter cost in dollars per foot to purchase and install the collector loop piping or ducting.
207	Additional Velocity Head Above Pipe, Valve and Tee Velocity Losses	If any additional velocity head loss exists that is not included in the piping, valve, tee or elbow losses, input this line number.
208	Pressure Head Loss (Collection Loop)	If any head losses in the collection loop exist due to unaccounted pressure changes, input this line.
209	Elevation Head (Collection Loop)	If any elevation head losses exist in the collector loop such as those encountered in by pipe openings in a drain down system, input this line.
210	Design Pipe Velocity	The pipe bulk velocity is not allowed to exceed this amount by selecting the pipe diameter. See Appendix D for details.
211	Number of Valves (Integer) in Collection Loop	Total number of valves in the collection loop. This number is used to calculate total head loss and subcomponent costs.
212	Number of Elbows (Integer) in Collection Loop	Total number of elbows in the flow loop. This number is used to calculate total head loss and subcomponent costs.
213	Number of Tees (Integer) in Collection Loop	Total number of tees in the collection loop (flow in one side only). This number is used to calculate total head loss and subcomponent costs.
214	Specific Heat of Collector Fluid	Enter the specific heat of the collector fluid in Btu/lbm-°F. This input is used for heat exchanger selection and calculating the collector outlet temperature.

Line No.	Input Parameter	Explanations/Options
215	Specific Heat of Storage Fluid	This is the specific heat of the storage fluid used for liquid systems. This input parameter is used exclusively for sizing heat exchangers.
217	Cost Per Elbow	Enter the cost per elbow including materials and installation.
218	Cost Per Valve	Enter the cost per valve including materials and installation.
219	Cost Per Tee	Enter the cost per tee including materials and installation.
221	Friction Factor for Velocity Head Loss Calculation	This is the friction factor as obtained from a Moody diagram which may be seen in most texts dealing with fluid mechanics. For example, Streeter, V.L. The default friction factor is for relatively smooth pipes such as extruded copper with a Reynolds number in excess of 10 million. This factor is a function of roughness, bulk pipe velocity and the viscosity of the fluid used in the collection loop.
222	Equivalent Pipe Length Per Valve at Ref. Dia = 12 In.	This is the equivalent length of pipe valve at a reference diameter equal to 12 inches. SOLCOST internally scales this equivalent length for diameters other than 12 inches. See Figure III-2 for suggested input values other than those defaulted.
223	Equivalent Pipe Length Per Elbow at Ref. Dia. = 12 In.	Equivalent pipe length per elbow at a reference diameter of 12 inches. SOLCOST internally compensates for diameters other than 12 inches by scaling. See Figure III-2 for suggested values other than those defaulted.
224	Equivalent Number of Feet Per Tee at Ref. Dia. = 12 In.	Equivalent number of feet per tee at a reference diameter of 12 inches. SOLCOST compensates internally for diameters other than 12 inches. It also assumes that flow is through one side of the tee only. See Figure III-2 for suggested equivalent lengths other than those defaulted.

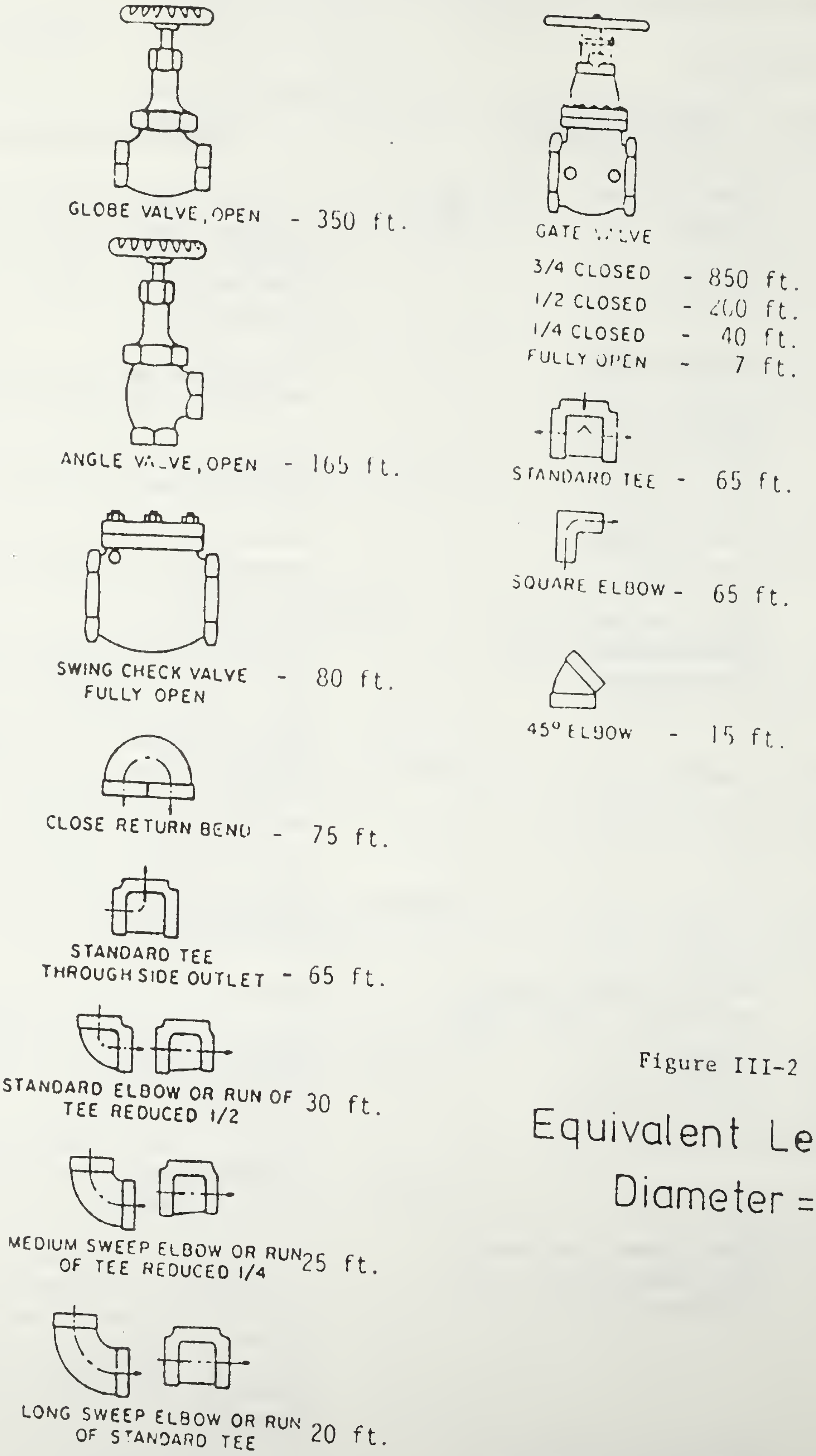
GLOBE VALVE, OPEN - 350 ft.
ANGLE VALVE, OPEN - 165 ft.
SWING CHECK VALVE FULLY OPEN - 80 ft.
CLOSE RETURN BEND - 75 ft.
STANDARD TEE THROUGH SIDE OUTLET - 65 ft.
STANDARD ELBOW OR RUN OF TEE REDUCED 1/2 30 ft.
MEDIUM SWEEP ELBOW OR RUN OF TEE REDUCED 1/4 25 ft.
LONG SWEEP ELBOW OR RUN OF STANDARD TEE 20 ft.
GATE VALVE
3/4 CLOSED - 850 ft.
1/2 CLOSED - 200 ft.
1/4 CLOSED - 40 ft.
FULLY OPEN - 7 ft.
STANDARD TEE - 65 ft.
SQUARE ELBOW - 65 ft.
45° ELBOW - 15 ft.

Figure III-2

Equivalent Length of Pipe
Diameter = 12 in.

Line No.	Input Parameter	Explanations/Options
	HEAT EXCHANGERS (AIR OR LIQUID)	
225	Storage Side of Heat Exchanger Multiplier	The mass capacitance flow rate for the storage side of the heat exchanger is assumed to be a multiple of the mass capacitance flow rate of the collectors where the multiplication factor is this line number input.
227	F_R'/F_R Ratio for Collector Heat Exchanger	The penalty that the user is willing to pay for inclusion of an exchanger in the collection loop for liquid systems. See Appendices C and E for more discussion of this particular parameter. Also, the collector parameters are not modified to reflect any degradation.
230	Design Point for Crossflow Load HX-Liq. Space Heating (Ratio of $\varepsilon C_{min}/UA_{load}$)	The effectiveness of the load heat exchanger for liquid systems is computed using this design point input. See Appendix D for a detailed explanation of how the design point plays a role in the heat exchanger selection.
231	Load HX Air Flow Rate	Load heat exchanger air flow rate is input in standard cubic feet per minute. It is assumed that this flow rate is constant irregardless of collector area.
232	Load HX (Liq-to-Air) Water Flow Rate (Also Service Water Coil in Air Systems)	Flow rate of water in gallons per minute for the liquid side of crossflow heat exchangers for both the load heat exchanger and liquid systems and the service hot water coil in air systems.
233	Duct Design Air Velocity	A duct diameter is selected so that the average air velocity is not allowed to exceed this amount. See Appendix D for more discussion.
234	Air Collector Design Flow Rate	The total standard flow rate of the collector is equal to this line number times the total area. This input is in standard cubic feet per minute (SCFM).

Line No.	Input Parameter	Explanations/Options
	HEAT EXCHANGERS (AIR OR LIQUID)(cont.)	
235	Air Collector Pressure Drop	Air pressure drop is input in inches of water. SOLCOST assumes that this pressure drop is independent of collector area. In other words, it is proportional only to the length of collector that the air must travel through or the module length.
236	Air System Service Water Coil Pressure Drop	This is the pressure drop in inches of water of the service hot water coil in the air space heating system. It is assumed to be constant irregardless of the collector area.
238	Solar System Site Elevation	This is the altitude of the location where the solar system is being built in feet. It is used to adjust the density of air for a calculation of duct dimensions.
239	Rock Bed Pressure Drop	The total pressure drop of the rock bed in the air system in inches of water.
240	Air System Service Hot Water Coil Effectiveness	Input an effectiveness for each candidate collector area.
250	No. of turns in Air System Collection Ducting (Integer)	Total number of turns in the air system collection loop. This number is used to calculate the total air system pressure drop in the cost of installation.
251	No. of Normally Open Dampers in Air Systems	The number of the normally open dampers in the air system collection loop. This number is used to calculate the total system pressure drop and the cost of installing the solar system.
252	Installed Cost Per Turn in Air Systems	Total cost for installing a turn or elbow in air systems. Includes both materials and labor.

Line No.	Input Parameter	Explanations/Options
240	Air System Service Hot Water Coil Effectiveness	Input an effectiveness for each candidate collector area.
241	Maximum Duct Pressure Drop per 100 ft of Duct	When the SOLCOST program calculates the duct diameter it checks to see that the pressure drop per 100 ft of duct does not exceed this amount. If it does it recalculates the diameter and then the square duct dimension for a side.
242	Flag to Indicate that SOLCOST is to Calculate the Rock Box Pressure Drop	Input a "1" so that SOLCOST will ignore line 243 and then use lines 244 and 245 to calculate the rock box pressure drop in inches of water.
243	Rock Bed Pressure Drop	The total pressure drop of the rock bed in the air system in inches of water. Used if line 242 is equal to zero.
244	Rock Bed Inside Height	Put the height of the rocks between the two bed plenums. SOLCOST uses this number to calculate the pressure drop through the bed if line 242 is input as a "1".
246	Maximum Number of Branches for Collector Manifold when the SOLCOST Program is Sizing the Manifolds for Air System Collector Arrays	This is the maximum number of branches which can be utilized, normally 10.

Line No.	Input Parameter	Explanations/Options
	HEAT EXCHANGERS (AIR OR LIQUID)(cont.)	
253	Installed Cost Per Normally Open Damper in Air Systems	This is the total cost for dampers in the air system. It includes both materials and labor.
254	Equivalent Length of Duct for Each Turn at Ref. Dia. = 1.0 Ft.	This is the total equivalent length of duct for each turn or elbow at a reference diameter of 1 foot. See Figure III-3 for suggested equivalent lengths of round duct other than as defaulted.
255	Equivalent Length of Duct for Each Damper at Ref. Dia. = 1.0 Ft.	This is the equivalent length of duct for each damper installed in the air space heating system collection loop. This input is used to determine the total pressure drop of this loop.
	PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS	
280	No. of Points in Candidate Pump (Head, Flow) Subset	Each number in this array corresponds to the number of flow versus head drop points that exist in arrays 281 and 282. See Table III-10 for example. The first element as defaulted for array 280 is a 4 which means there are 4 flow versus head drop points for this particular pump.
281	Pump Head Values for Candidata Pumps	Input the head drop for each of the pumps to be used in the selection procedure. See Table III-10 for example. For the first pump there are four head drop values which correspond to flow rates. Input these in decreasing order. In other words, the highest drop goes first. After all of the head drops are input for the first pump, proceed to the next pump. SOLCOST internally separates the pump head drop data points depending on what values are input in array 280.

Line No.	Input Parameter	Explanations/Options
260	Total Systems* Optimization Flag (Integer)	0 = Not executed 1 = Executed and short output 2 = Executed with cash flow table output
261	Structure Property Tax Rate	SOLCOST uses this parameter to calculate the property tax paid over time for improvements to reduce the structures total energy requirements.
271	Load and Cost Paired Inputs for Heat Load Reducing Features in the Form of Wall Insulation	The input pairs (up to 10) should contain the net heat load per degree-day per square foot of floor area (same form as line 42) and the cost for including the option to change from the line 42 input to the new net load factor input in this line.
272	Same as 271 but for Ceiling Insulation	
273	Same as 271 but for Windows	
274	Same as 271 but for Doors	
275	Same as 271 but for Infiltration Reducing Features	

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[*] See Appendix E for details and an example.

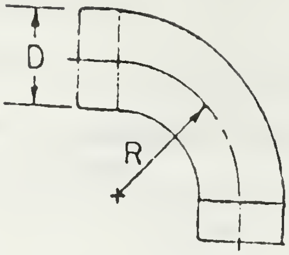
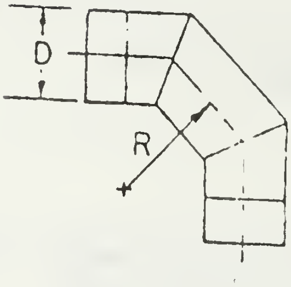
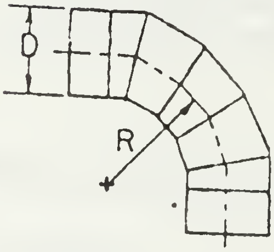
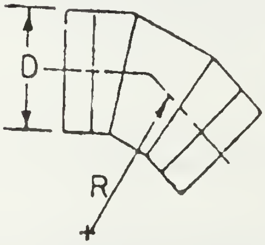
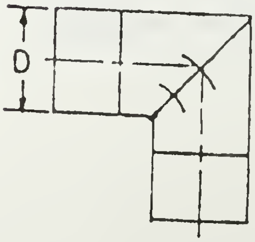
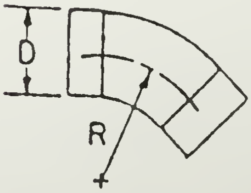
		Length-ft.
90° SMOOTH ELBOW R/D = 1.5		6
90° 3-PIECE ELBOW R/D = 1.5		17
90° 5-PIECE ELBOW R/D = 1.5		12
45° 3-PIECE ELBOW R/D = 1.5		6
90° MITER ELBOW R/D = .5		22 Vaned 65 Not Vaned
45° SMOOTH ELBOW R/D = 1.5		4.5

Figure III-3

Equivalent Length of Round Duct [D=12in]

Line No.	Input Parameters	Explanations/Options
	PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS (cont.)	
282	Pump Flow Values Corresponding to Heads in Line 281	These are the corresponding flow rates in gallons per minute for the head drops input in array 281. See Table III-10 for default values.
283	Costs for Candidate Pumps	Cost of the input pumps used in the selection process. The first value for default (see Table III-10) is 75, the second value is 100, etc.
290	No. of Points in Crossflow HX Cost and UA Arrays (Integer)	Input the total number of crossflow heat exchanger cost versus UA values that are included in the array inputs 291 and 292.
291	Crossflow HX Costs	Input costs for the crossflow heat exchangers in increasing order.
292	Crossflow HX UA	Input the corresponding UA value for the crossflow heat exchangers whose costs are listed in array 291.
295	No. of Points in Counterflow HX Cost and UA Arrays (Integer)	This is the number of counterflow heat exchangers whose costs and UA's are listed in arrays 296 and 297. This input cannot exceed 10. Input is similar to line 290.
296	Counterflow HX Costs	See Table III-12 for costs of default heat exchangers. Input these in increasing order.
297	Counterflow HX UA	Input the corresponding heat exchanger UA values for the costs inputted in Line 296. Also, see Table III-12 for default values.
300	No. of Points in Candidate Fan Subsets	This is an array of values where each value corresponds to the number of data point pairs for each fan in the fan head and flow rate arrays. See Table III-13. For example, a first value in this array is 5, which means there are 5 fan head versus flow rate point pairs in arrays 301 and 302.

TABLE III-10. PUMP SELECTION TABLE (DEFAULT)

Number	Flow(GPM)	Head(Ft)	Cost($)
1	0.00	9.50	75.00
1	5.00	8.50	75.00
1	10.00	7.00	75.00
1	19.00	1.20	75.00
2	0.00	14.00	100.00
2	22.00	0.00	100.00
3	0.00	10.00	105.00
3	5.00	6.50	105.00
3	7.50	4.00	105.00
3	10.00	1.70	105.00
4	0.00	8.00	112.00
4	16.00	0.00	112.00
5	0.00	20.00	112.00
5	30.00	0.00	112.00
6	0.00	6.00	135.00
6	14.00	0.00	135.00
7	0.00	14.00	171.00
7	23.00	0.00	171.00
8	0.00	40.00	225.00
8	30.00	0.00	225.00
9	0.00	20.00	225.00
9	60.00	0.00	225.00

TABLE III-11. CROSSFLOW HEAT EXCHANGER UA VS. COST TABLE (DEFAULT)

Number	UA(Btu/hr-°F)	Cost($)
1	197.00	45.00
2	295.50	50.00
3	394.00	55.00
4	492.50	63.00
5	591.00	77.00
6	788.00	84.00
7	886.50	85.00
8	985.00	100.00
9	1773.00	128.00
10	1940.00	140.00
11	3546.00	192.00

TABLE III-12. COUNTERFLOW HEAT EXCHANGER UA VS. COST TABLE (DEFAULT)

Number	UA(Btu/hr-°F)	Cost($)
1	715.00	112.00
2	1430.00	158.00
3	2172.00	190.00
4	3080.00	292.00
5	4620.00	338.00
6	6160.00	382.00
7	7205.00	482.00
8	9570.00	553.00
9	14492.00	796.00
10	22990.00	925.00
11	27527.00	1040.00
12	32065.00	1144.00
13	36602.00	1313.00
14	45952.00	1690.00

TABLE III-13. FAN TABLE (DEFAULT)

Number	Fan Head(In. of Water)	Flow Rate(CFM)	Cost($)
1	0.00	148.00	25.00
1	.20	135.00	25.00
1	.40	121.00	25.00
1	.50	114.00	25.00
1	1.04	0.00	25.00
2	0.00	525.00	55.00
2	.20	475.00	55.00
2	.40	415.00	55.00
2	.50	387.00	55.00
2	1.15	0.00	55.00
3	.30	865.00	60.00
3	.40	825.00	60.00
3	.50	760.00	60.00
3	.60	660.00	60.00
3	.70	520.00	60.00
4	1.00	291.00	80.00
4	2.00	231.00	80.00
4	3.00	156.00	80.00
4	4.00	0.00	80.00
5	1.00	530.00	85.00
5	2.00	475.00	85.00
5	3.00	415.00	85.00
5	4.00	335.00	85.00
5	5.00	160.00	85.00

TABLE III-13. FAN TABLE (DEFAULT) (cont.)

Number	Fan Head(In. of Water)	Flow Rate(CFM)	Cost($)
6	.13	1100.00	100.00
6	.25	1000.00	100.00
6	.38	890.00	100.00
6	.50	800.00	100.00
6	.75	475.00	100.00
6	1.00	0.00	100.00
7	1.50	1848.00	175.00
7	1.75	1735.00	175.00
7	2.00	1610.00	175.00
7	2.25	1457.00	175.00
7	2.50	1288.00	175.00
7	2.75	1047.00	175.00
8	.50	2100.00	180.00
8	.75	1980.00	180.00
8	1.00	1460.00	180.00
9	1.00	1200.00	210.00
9	2.00	1137.00	210.00
9	3.00	1069.00	210.00
9	4.00	1011.00	210.00
9	4.50	937.20	210.00
10	1.00	2137.00	330.00
10	3.00	1927.00	330.00
10	5.00	1711.00	330.00

Line No.	Input Parameters	Explanations/Options
	PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS (cont.)	
301	Fan Head Values for Candidata Fans	Input the fan pressure drop in inches of water for each fan to be considered in the selection process.
302	Fan Flow Values Corresponding to Heads in Line 301	Input the corresponding flow rates for the fan pressure drop input in array 301.
303	Costs for Candidate Fans	Input the individual costs for each of the fans inputted in arrays 300, 301, and 302. Enter one cost per fan; not to exceed 10 costs.

APPENDIX C

FCHART WEATHER DATA FOR MONTANA
SOLCOST WEATHER DATA FOR MONTANA

FCHART WEATHER DATA FOR MONTANA

```
  245 ANACONDA       MT            46.12      60.00      00.00
10800 10800 14760 15120 13320 14760 16920 15480 16560 15840 10080  8280
  735   595   613   425   278   163    40    62   191   346   548   675
   -5    -3    -1     4     9    13    19    18    12     7     0    -3
  246 BILLINGS       MT            45.78      60.00      00.00
11880 13680 15840 16560 15120 16920 17280 17280 18720 16560 12600  9720
  720   548   518   301   160    67     6    12   122   263   476   640
   -5    -1     2     8    13    17    22    21    15    10     2    -2
  247 BOZEMAN        MT            45.67      60.00      00.00
10440 12240 16200 16920 14400 16560 18000 17640 17640 16560 10440  7920
  762   614   596   377   238   128    25    38   160   322   542   682
   -6    -3    -1     6    11    14    19    18    13     8     0    -4
  248 BROWNING       MT            48.55      60.00      00.00
11160 12600 15840 17640 15480 16560 16920 17280 17640 15480 12960  9360
  809   643   654   438   289   175    61    92   219   360   571   715
   -8    -5    -3     4     9    13    17    16    11     7    -1    -5
  249 BUTTE          MT            46.00      60.00      00.00
12600 12600 15120 16200 13320 14760 17280 17280 16920 15480 12240  9000
  859   686   678   455   313   187    66    92   242   411   618   788
   -9    -6    -4     3     8    12    17    16    10     5    -2    -7
  250 CHOTEAU        MT            47.82      60.00      00.00
11520 11520 15480 16560 15120 16920 18000 17280 17280 16200 11520  8280
  756   595   594   378   230   117    26    47   177   310   520   665
   -6    -3    -1     6    11    15    19    18    13     8     1    -3
  251 COLSTRIP       MT            45.88      60.00      00.00
11880 13320 16200 16560 14760 17280 17640 18000 19080 17280 11160  9000
  753   585   556   346   177    58     6    13   112   277   508   667
   -6    -3     0     7    12    17    22    21    15     9     1    -4
  252 DILLON         MT            45.25      60.00      00.00
12600 14760 16560 18000 15480 16920 18360 17640 19440 18360 12960 10080
  737   585   577   381   246   130    27    55   177   325   525   676
   -5    -3    -0     6    10    14    18    17    13     8     1    -4
  253 ENNIS          MT            45.35      60.00      00.00
12240 14040 16920 16920 14400 16200 15480 16560 18720 17640 12240 10080
  730   583   580   386   251   138    37    52   186   330   520   657
   -5    -3    -0     5    10    14    18    17    12     8     1    -3
  254 FORT BENTON    MT            47.80      60.00      00.00
 9360 11880 14760 14760 14040 16920 18720 18000 16920 14760  9720  6480
  806   605   571   330   176    78     8    18   140   294   523   701
   -7    -3    -0     7    13    17    21    20    14     9     1    -4
   255 GLASGOW         MT             48.20       60.00        00.00
 11880 14040 16560 16920 16560 18000 18720 17280 16920 16200 11160  8640
   938   785   630   343   183    72     8    18   145   336   616   847
   -12   -10    -2     7    13    18    22    21    14     8    -2    -9
   256 GLENDIVE        MT             47.12       60.00        00.00
 11880 12600 15480 15840 16560 17280 17280 17640 17640 13320 10440  7560
   862   692   596   313   136    50     4     7   113   268   531   742
   -10    -6    -1     8    14    19    23    22    16    10     1    -6
   257 GREAT FALLS     MT             47.52       60.00        00.00
  9720 12600 15120 16560 15480 17640 18360 18000 17280 15120 11520  9360
   766   597   594   360   203    90    10    23   144   291   506   663
    -6    -3    -1     6    12    16    21    20    14     9     1    -3
   258 HAMILTON        MT             46.25       60.00        00.00
  9000 10080 14400 16200 14400 16200 16920 18000 14760 15840  9720  6840
   692   525   496   321   201    95    15    36   148   318   503   638
    -4    -0     2     8    12    15    20    19    14     8     2    -2
   259 HARLOWTON       MT             46.43       60.00        00.00
 11880 13680 17280 17280 15120 16920 18000 17280 18360 15840 11520 10080
   745   601   604   394   235   115    25    45   177   311   533   658
    -6    -4    -1     6    11    14    19    18    13     8     0    -3
   260 HAVRE           MT             48.57       60.00        00.00
 10800 12960 16200 16200 16200 16560 15480 14040 16560 14040 11160  7920
   840   717   597   331   173    69    11    21   150   313   568   768
    -9    -7    -1     7    13    17    22    20    14     8    -1    -6
   261 HELENA          MT             46.58       60.00        00.00
 10440 12600 15480 17280 14400 15840 15840 16560 18000 16200 11520  8640
   798   650   578   361   211   108    17    32   163   333   556   702
    -7    -5    -0     6    12    15    20    19    13     8    -0    -4
   262 JORDON          MT             47.32       60.00        00.00
 11520 12600 15840 17280 16200 17280 18000 18720 18720 16560 11520  8280
   862   675   609   341   175    70     7    12   133   305   551   754
   -10    -6    -1     7    13    18    22    21    15     9    -0    -6
   263 KALISPELL       MT             48.22       60.00        00.00
  8640  9000 13680 15840 14400 16920 16920 17280 15840 14400  7560  5040
   770   622   538   355   217   119    26    46   181   355   550   693
    -7    -4     1     7    11    15    19    18    13     7     0    -4
   264 LEWISTOWN       MT             47.07       60.00        00.00
 11520 14400 16200 17280 15480 17640 17640 17280 17640 16200 11520 10080
   776   635   638   422   253   125    36    46   178   322   546   677
    -7    -5    -2     5    10    14    19    18    13     8     0    -4
  265 LIBBY           MT           48.40      60.00      00.00
 9360  8280 13320 15480 14040 16560 16920 17280 14400 12960  6480  6840
  716   550   510   331   189    88    26    35   140   340   547   655
   -6    -2     2     8    12    16    20    19    14     8     0    -3
  266 LIVINGSTON      MT           45.65      60.00      00.00
10800 11880 15480 15840 15840 18000 18000 18720 18720 15840 12240  7920
  668   537   541   361   211    91    20    30   134   271   484   584
   -4    -2     1     6    11    15    20    19    14     9     2    -1
  267 MILES CITY      MT           46.42      60.00      00.00
12600 14400 16560 16920 15840 17640 17640 16920 17640 16200 11160  9360
  835   695   587   321   153    55     3     3    96   278   540   720
   -9    -7    -1     8    14    19    24    23    16     9     0    -5
  268 MISSOULA        MT           46.87      60.00      00.00
 8640  8640 12960 15120 13320 16200 16920 17280 15480 15480  8280  5400
  785   611   521   338   202    97    12    31   162   346   551   712
   -7    -4     2     7    12    16    20    19    13     7    -0    -5
  269 PLENTYWOOD      MT           48.78      60.00      00.00
12600 14760 15840 14760 15840 17280 18000 18360 17280 15480 10440  9000
  983   799   702   381   191    75    11    20   152   330   616   859
  -13   -10    -4     6    12    17    21    20    14     8    -2    -9
  270 POLSON          MT           47.68      60.00      00.00
 7200  9000 14040 15840 14400 16560 17280 17280 15840 15120  6840  5400
  667   553   530   346   216   100    31    31   146   338   518   608
   -4    -2     2     7    12    15    20    19    14     8     1    -1
  271 RED LODGE       MT           45.18      60.00      00.00
12960 13680 16200 15480 14400 15840 16200 15840 18000 17280 12960 10800
  717   594   610   429   262   142    38    54   185   329   534   652
   -5    -4    -2     4     9    13    18    17    12     7     0    -3
  272 SIDNEY          MT           47.70      60.00      00.00
12240 14040 16920 13680 13680 15840 16200 16200 17640 15840 10800  8640
  911   727   638   350   175    65     9    18   140   306   575   788
  -11    -8    -2     7    13    18    22    21    14     8    -1    -7
  273 THOMPSON FALL MT             47.58      60.00      00.00
11160  7560 12600 14400 13320 15840 16200 14400 14400 13680  6480  3600
  646   495   470   308   172    74    17    25   109   288   480   601
   -3     1     3     8    13    16    20    20    15     9     2    -1
  274 W YELLOWSTONE MT             44.92      60.00      00.00
11160 12960 15840 18000 14400 16200 17280 15480 19440 18000  9360  9000
  910   756   744   526   353   217    83   127   272   464   702   884
  -11    -8    -5     1     7    11    15    14     9     3    -5   -10
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337    46.1  1.00      ANACONDA      MT
   14.7  17.0  21.5  30.3  38.1  45.1  52.7  50.9  43.1  34.8  24.8  18.6
   29.2  32.8  39.0  49.5  59.5  67.8  79.0  76.9  65.7  53.6  39.5  32.3
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1324.01072.01104.0 765.0 502.0 294.0  72.0 112.0 344.0 623.0 987.01215.0
  445.5 617.51083.11436.41505.51723.01916.11583.51337.2 928.6 463.1 326.2
338    45.8  1.00      BILLINGS      MT
   11.5  14.8  21.7  31.9  41.2  48.1  54.1  51.2  42.2  33.6  23.2  17.0
   36.1  41.1  48.2  62.3  71.4  77.8  88.6  87.0  76.9  65.5  48.5  41.3
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1296.0 988.0 933.0 543.0 288.0 121.0  11.0  23.0 221.0 474.0 858.01153.0
  486.0 748.51154.51563.71711.81983.11963.01759.81492.6 970.1 556.2 374.7
339    45.7  1.00      BOZEMAN       MT
   10.1  15.8  19.2  30.4  38.5  44.9  51.1  49.4  41.5  33.4  21.9  15.5
   30.7  35.8  41.0  53.7  63.3  70.2  81.5  80.3  69.5  58.7  42.4  34.9
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1372.01106.01074.0 680.0 429.0 232.0  45.0  70.0 288.0 581.0 976.01229.0
  442.6 688.91178.31596.11632.81942.82045.81796.11421.1 972.8 483.9 322.2
340    48.6  1.00      BROWNING      MT
    8.4  10.1  16.2  26.9  35.3  41.2  45.6  43.7  37.0  30.1  19.5  13.4
   29.0  31.1  38.1  51.0  61.5  68.0  78.0  76.0  65.3  54.6  40.1  32.8
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1457.01159.01178.0 789.0 521.0 315.0 111.0 167.0 395.0 648.01029.01287.0
  408.3 646.41095.01596.11706.31888.91870.01704.61355.7 855.6 507.3 315.2
341    46.0  1.00      BUTTE         MT
    1.5   5.5  13.7  25.7  33.5  40.1  45.1  42.5  34.8  26.8  15.0   7.7
   27.8  32.7  39.1  50.9  60.7  67.9  80.0  78.0  67.5  56.3  40.3  32.5
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1547.01235.01221.0 819.0 564.0 337.0 119.0 166.0 437.0 741.01113.01420.0
  503.6 698.01107.01529.31507.11724.91958.41755.31364.4 914.6 539.4 349.7
342    47.8  1.00      CHOTEAU       MT
    8.2  10.8  18.2  28.0  36.9  44.2  49.2  46.3  38.7  31.1  20.1  14.8
   33.2  36.6  43.8  55.2  65.4  72.3  82.7  80.8  69.6  59.9  45.4  38.4
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1361.01072.01070.0 681.0 415.0 212.0  47.0  85.0 320.0 558.0 936.01197.0
  433.3 617.41090.41524.31679.01942.81999.41718.91348.7 904.4 478.7 299.0
343    45.9  1.00      COLSTRIP      MT
    7.7  13.9  18.9  30.1  39.4  47.7  53.8  52.1  42.0  32.4  21.1  12.8
   34.2  39.8  45.8  59.3  69.2  77.6  89.2  88.1  75.9  64.8  47.5  38.2
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1356.01053.01001.0 624.0 319.0 105.0  12.0  24.0 203.0 500.0 915.01202.0
  484.0 731.11173.81561.71669.92023.42001.01825.61514.81001.1 505.1 351.7
344    45.3  1.00      DILLON        MT
   11.7  15.3  21.5  29.9  36.9  42.7  47.7  45.1  37.2  30.7  21.5  15.1
   34.2  38.3  45.2  55.9  65.4  73.8  82.6  81.1  71.4  61.4  46.5  37.2
  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
 1327.01053.01039.0 687.0 443.0 235.0  50.0 100.0 319.0 586.0 945.01218.0
  519.8 806.01209.11696.01761.41994.22095.81805.01555.31067.9 579.8 394.9
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345     45.4  1.00       ENNIS           MT
     11.6  14.7  20.3  28.3  35.8  42.3  47.3  44.9  37.5  30.9  21.9  16.5
     31.8  36.0  43.4  55.4  65.5  73.3  82.8  81.0  71.0  59.5  44.0  35.6
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1314.01050.01045.0 696.0 453.0 249.0  68.0  94.0 336.0 595.0 936.01184.0
    506.3 773.11228.41602.61637.71906.41769.51700.01503.01031.4 552.9 393.1
346     47.8  1.00       FORT BENTON     MT
      8.7  10.4  19.2  31.5  40.9  48.6  53.4  50.9  42.2  33.2  21.9  15.1
     32.1  34.9  43.9  59.7  68.4  74.9  85.3  83.3  72.7  62.7  45.0  37.6
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1451.01089.01029.0 594.0 317.0 141.0  16.0  33.0 253.0 530.0 942.01262.0
    370.5 632.51049.61378.31562.21943.22077.21784.81325.5 841.1 421.1 248.0
347     48.2  1.00       GLASGOW         MT
      1.4   5.2  19.4  33.0  42.6  51.2  57.6  54.3  43.8  33.1  18.0   6.6
     19.6  23.7  37.4  55.7  68.4  75.9  86.7  83.5  70.5  57.9  37.9  24.9
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1690.01414.01135.0 618.0 330.0 131.0  15.0  34.0 262.0 605.01110.01525.0
    435.5 710.21143.01545.81827.92057.62068.41711.41316.8 895.2 459.8 302.5
348     47.1  1.00       GLENDIVE        MT
      3.0   5.3  17.4  32.5  43.0  52.3  58.2  55.0  44.1  33.0  20.2   9.5
     25.3  28.8  41.4  59.9  71.3  79.6  89.2  87.3  74.9  62.1  43.0  31.0
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1553.01246.01073.0 564.0 246.0  90.0   8.0  13.0 204.0 484.0 957.01336.0
    458.2675.51105.11478.61847.61997.71935.81765.91388.2  790.3 457.2 289.4
349     47.5  1.00       GREAT FALLS     MT
     11.6  17.2  20.6  32.3  41.5  49.5  54.9  53.0  44.6  37.1  25.7  18.2
     29.3  35.9  40.4  54.5  65.0  72.1  83.7  81.8  70.0  59.4  43.4  34.7
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1380.01075.01070.0 648.0 367.0 162.0  18.0  42.0 260.0 524.0 912.01194.0
    386.3 667.41076.01530.01722.82030.82044.51790.61355.4 863.5 484.7 333.5
350     46.3  1.00       HAMILTON        MT
     15.7  19.2  26.2  33.2  39.7  45.7  50.8  48.8  41.7  33.6  25.2  19.1
     34.4  39.3  48.6  60.0  68.4  75.1  85.2  83.1  72.2  60.0  45.6  36.6
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1246.0 946.0 893.0 579.0 362.0 171.0  27.0  66.0 267.0 574.0 906.01150.0
    385.6 583.31059.11524.51624.01889.31913.51817.61211.1 925.5 448.2 279.9
351     46.4  1.00       HARLOWTON       MT
      9.8  12.9  17.0  27.7  36.2  43.0  48.6  45.3  37.5  30.7  20.0  15.0
     33.6  38.0  43.4  56.5  66.4  72.2  83.3  81.8  71.4  61.5  45.6  38.3
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1342.01083.01088.0 710.0 424.0 207.0  46.0  82.0 319.0 561.0 961.01186.0
    472.6 734.61224.91610.71701.11969.92029.01746.61452.5 921.3 506.5 373.2
352     48.6  1.00       HAVRE           MT
      6.1   8.1  19.5  32.5  42.6  50.6  56.6  53.1  42.9  33.7  20.2  10.3
     26.3  29.6  41.0  57.6  68.8  75.2  85.9  82.9  71.0  59.8  41.5  30.4
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1513.01291.01076.0 597.0 313.0 125.0  20.0  38.0 270.0 564.01023.01383.0
    397.9 660.11114.61481.21782.91888.61716.61411.51285.4 792.4 452.4 277.3
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353     46.6  1.00       HELENA          MT
      8.4  12.7  20.2  30.5  39.9  46.6  52.3  50.1  41.2  32.3  20.8  14.2
     28.8  33.7  42.5  56.1  65.8  72.3  84.4  82.2  70.8  58.8  42.4  34.2
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1438.01170.01042.0 651.0 381.0 195.0  31.0  59.0 294.0 601.01002.01265.0
    425.6 686.41116.41607.71619.01841.31788.21676.51424.7 934.3 503.5 329.4
354     47.3  1.00       JORDON          MT
      2.7   4.8  16.8  29.6  40.0  48.8  55.3  52.1  41.1  30.3  17.9   8.7
     28.1  31.7  43.2  59.0  70.0  78.6  90.3  87.7  75.9  62.6  44.8  34.4
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1553.01215.01097.0 615.0 316.0 127.0  14.0  22.0 240.0 549.0 993.01358.0
    443.5 671.51121.61592.51804.61993.62009.91860.81455.3 932.6 488.7 307.0
355     48.2  1.00       KALISPELL       MT
     12.6  15.8  24.1  32.2  39.8  45.4  49.9  47.4  40.0  32.9  24.9  18.2
     28.0  34.1  43.2  55.2  65.0  71.4  82.1  80.5  68.9  55.8  39.1  31.2
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1386.01120.0 970.0 639.0 391.0 215.0  47.0  83.0 326.0 639.0 990.01249.0
    341.7 504.5 979.41458.71595.31935.41876.01711.01245.7 815.9 341.5 199.2
356     47.1  1.00       LEWISTOWN       MT
      8.2  10.5  17.4  28.0  37.2  44.2  50.2  48.3  40.1  32.3  20.5  14.2
     31.0  34.4  39.8  53.5  63.8  70.4  81.9  80.4  69.6  59.8  43.8  37.0
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1397.01143.01149.0 760.0 456.0 225.0  66.0  84.0 322.0 581.0 984.01219.0
    448.6 750.01147.81597.61730.22040.11976.01733.81389.4 922.5 493.8 361.3
357     48.4  1.00       LIBBY           MT
     13.1  17.1  23.2  29.4  36.7  42.5  45.2  43.0  37.9  33.2  24.7  20.3
     30.8  38.9  49.5  62.2  72.1  78.2  89.7  87.5  76.1  59.4  40.2  33.3
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1290.0 991.0 919.0 596.0 341.0 159.0  48.0  64.0 252.0 613.0 985.01179.0
    360.0 470.4 955.41426.61554.11891.51872.71707.51147.4 748.1 300.9 250.2
358     45.7  1.00       LIVINGSTON      MT
     15.1  18.2  22.2  30.7  38.7  45.4  51.3  49.4  42.2  35.5  25.5  21.2
     34.3  38.8  44.5  56.4  66.0  73.0  85.0  83.4  72.5  61.6  45.2  39.2
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1204.0 968.0 974.0 650.0 380.0 165.0  36.0  55.0 242.0 488.0 872.01052.0
    454.5 673.61135.71505.51794.82113.52046.21898.71495.7 939.5 546.7 322.5
359     46.4  1.00       MILES CITY      MT
      5.6   8.7  19.4  32.8  44.1  52.6  60.4  57.7  46.7  35.5  21.7  12.8
     27.4  31.8  42.3  58.6  70.6  78.5  90.2  87.5  75.2  62.4  43.5  33.6
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1504.01252.01057.0 579.0 276.0  99.0   6.0   6.0 174.0 502.0 972.01296.0
    494.5 764.61183.11581.11781.02054.01989.51713.21404.1 938.1 494.6 352.9
360     46.9  1.00       MISSOULA        MT
     10.1  15.6  23.7  31.4  39.4  45.5  50.4  48.3  40.1  31.7  22.9  15.5
     28.6  35.7  45.6  57.9  67.8  74.8  86.3  83.8  71.4  58.0  40.9  31.6
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1414.01100.0 939.0 609.0 365.0 176.0  22.0  57.0 292.0 623.0 993.01283.0
    363.8 508.6 961.51423.61495.71877.91901.41737.81248.6 894.6 387.0 225.7
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SOLCOST WEATHER DATA FOR MONTANA

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337     46.1  1.00       ANACONDA        MT
     14.7  17.0  21.5  30.3  38.1  45.1  52.7  50.9  43.1  34.8  24.8  18.6
     29.2  32.8  39.0  49.5  59.5  67.8  79.0  76.9  65.7  53.6  39.5  32.3
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1324.01072.01104.0 765.0 502.0 294.0  72.0 112.0 344.0 623.0 987.01215.0
    445.5 617.51083.11436.41505.51723.01916.11583.51337.2 928.6 463.1 326.2
338     45.8  1.00       BILLINGS        MT
     11.5  14.8  21.7  31.9  41.2  48.1  54.1  51.2  42.2  33.6  23.2  17.0
     36.1  41.1  48.2  62.3  71.4  77.8  88.6  97.0  76.9  65.5  48.5  41.3
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1296.0 988.0 933.0 543.0 288.0 121.0  11.0  23.0 221.0 474.0 858.01153.0
    486.0 748.51154.51563.71711.81983.11963.01759.81492.6 970.1 556.2 374.7
339     45.7  1.00       BOZEMAN         MT
     10.1  15.8  19.2  30.4  38.5  44.9  51.1  49.4  41.5  33.4  21.9  15.5
     30.7  35.8  41.0  53.7  63.3  70.2  81.5  80.3  69.5  58.7  42.4  34.9
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.006 0.000 0.000 0.000
   1372.01106.01074.0 680.0 429.0 232.0  45.0  70.0 288.0 581.0 976.01229.0
    442.6 688.91178.31596.11632.81942.82045.81796.11421.1 972.8 483.9 322.2
340     48.6  1.00       BROWNING        MT
      8.4  10.1  16.2  26.9  35.3  41.2  45.6  43.7  37.0  30.1  19.5  13.4
     29.0  31.1  38.1  51.0  61.5  68.0  78.0  76.0  65.3  54.6  40.1  32.8
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1457.01159.01178.0 789.0 521.0 315.0 111.0 167.0 395.0 648.01029.01287.0
    408.3 646.41095.01596.11706.31888.91870.01704.61355.7 855.6 507.3 315.2
341     46.0  1.00       BUTTE           MT
      1.5   5.5  13.7  25.7  33.5  40.1  45.1  42.5  34.8  26.8  15.0   7.7
     27.8  32.7  39.1  50.9  60.7  67.9  80.0  78.0  67.5  56.3  40.3  32.5
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1547.01235.01221.0 819.0 564.0 337.0 119.0 166.0 437.0 741.01113.01420.0
    503.6 698.01107.01529.31507.11724.91958.41755.31364.4 914.6 539.4 349.7
342     47.8  1.00       CHOTEAU         MT
      8.2  10.8  18.2  28.0  36.9  44.2  49.2  46.3  38.7  31.1  20.1  14.8
     33.2  36.6  43.8  55.2  65.4  72.3  82.7  80.8  69.6  59.9  45.4  38.4
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1361.01072.01070.0 681.0 415.0 212.0  47.0  85.0 320.0 558.0 936.01197.0
    433.3 617.41090.41524.31679.01942.81999.41718.91348.7 904.4 478.7 299.0
343     45.9  1.00       COLSTRIP        MT
      7.7  13.9  18.9  30.1  39.4  47.7  53.8  52.1  42.0  32.4  21.1  12.8
     34.2  39.8  45.8  59.3  69.2  77.6  89.2  88.1  75.9  64.8  47.5  38.2
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1356.01053.01001.0 624.0 319.0 105.0  12.0  24.0 203.0 500.0 915.01202.0
    484.0 731.11173.81561.71669.92023.42001.01825.61514.81001.1 505.1 351.7
344     45.3  1.00       DILLON          MT
     11.7  15.3  21.5  29.9  36.9  42.7  47.7  45.1  37.2  30.7  21.5  15.1
     34.2  38.3  45.2  55.9  65.4  73.8  82.6  81.1  71.4  61.4  46.5  37.2
    0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
   1327.01053.01039.0 687.0 443.0 235.0  50.0 100.0 319.0 586.0 945.01218.0
    519.8 806.01209.11696.01761.41994.22095.81805.01555.31067.9 579.8 394.9
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15 copies of this public document were published at an estimated cost of $9.34 per copy, for a total cost of $140.10, which includes $140.10 for printing and $.00 for distribution.